Chapter 1. Introduction

Objectives

The study reported here takes advantage of a set of new technologies for assessing environmental conditions at a landscape scale (Jones et al.,1997). The focus of this report is the watersheds of the Catskill/Delaware (CD) water supply system located in Region 2 of the U.S. Environmental Protection Agency's (EPA)(Figure 1.1). These watersheds and their reservoirs provide the majority of the drinking water for New York City. High speed computers, satellite imagery and historical databases with extensive spacial and temporal coverage now facilitate analyses of regional issues such as the status of the CD water supply system over time.

The purpose of this document is to provide (1) regional and local scale data that will assist land managers, policy makers, and the general public in making informed decisions on environmental and water resource issues; and (2) data analyses that help direct future land cover and land use practices critical to maintaining water quality. In this report the six watersheds making up the CD water supply system will be called the CD watersheds and Region 2 refers to the states of New York and New Jersey (although Region 2 also includes Puerto Rico, the U.S. Virgin Islands, and seven tribal Nations, only data related to the two states was used in the study of the CD watersheds). This study was conducted by the Landscape Ecology Branch of the EPA Office of Research and Development.

Overview

Selection of an area for study often depends on the local population's concern for a specified resource. In this case one of the major concerns for millions of people living in Region 2 is maintaining quality water for recreational, agricultural, and consumption purposes. One means of monitoring water quality is through the use of Total Maximum Daily Loads (TMDL; EPA, 1991). A TMDL is the amount of pollutants a water body can receive and still meet water quality standards set by States, territories, and Native American tribes. Water bodies that are not attaining water quality standards with technology based controls alone are placed on the State 303d list for TMDL determination. Almost 90% of all watersheds within New Jersey have more than a quarter of the water bodies on the 303d listing. In New York, less then 10% of the watersheds have more than a quarter of the water bodies listed as impaired; the other 90% list between 0 to 25%

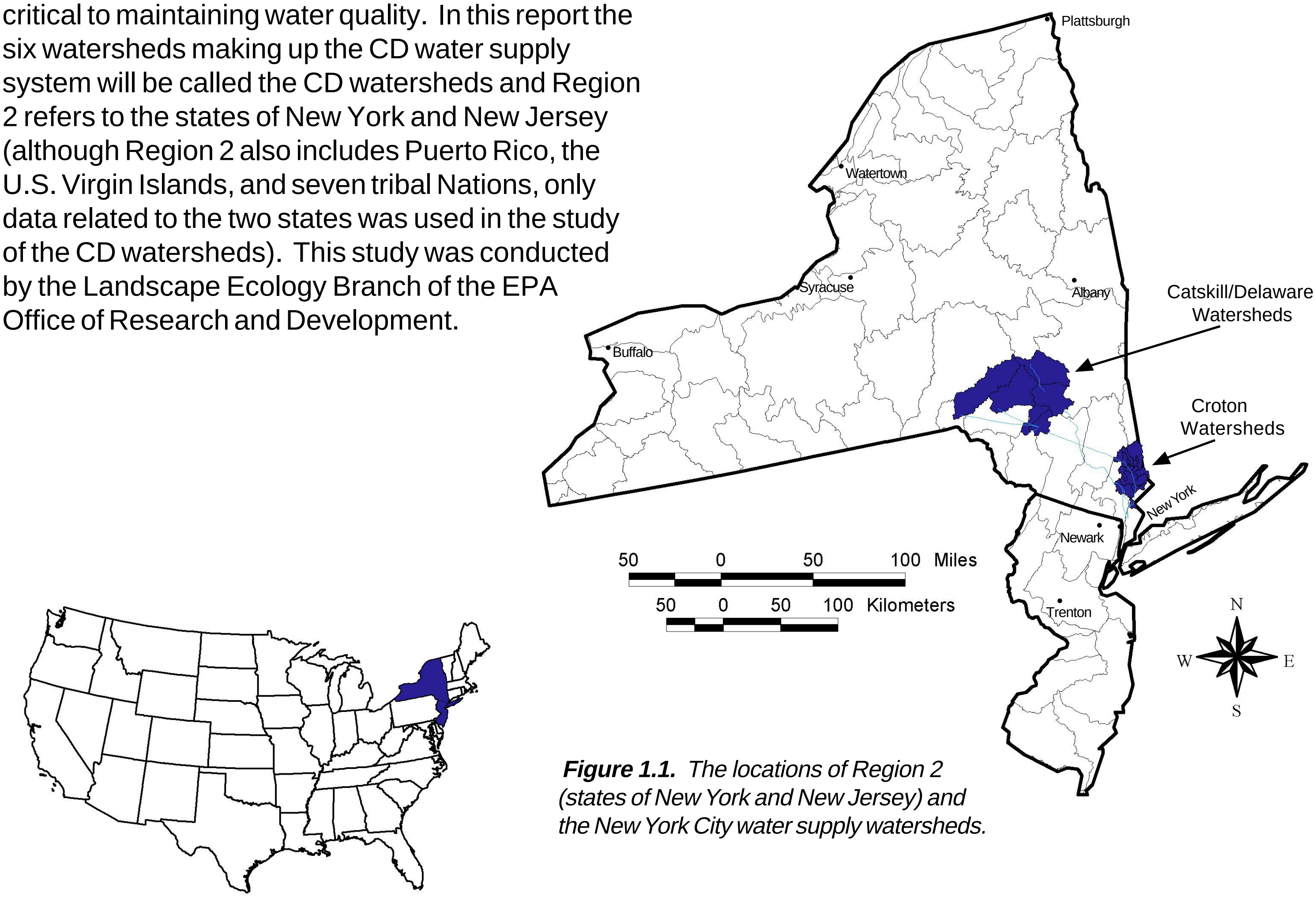


Figure 1.1. *The locations of Region 2 (states of New York and New Jersey) and the New York City water supply watersheds.*

(Figure 1.2). The majority of listings are the result of five pollutants: pH, pathogens, organic matter content, nutrients and sediments. Low pH is generally attributable to acid rain, while organic matter content, sediment, nutrients, and pathogens tend to be related to land use and erosion (EPA, 1998a). Nutrients and pathogens account for the impairment of close to 1,700 stream miles and 100,000 acres of Region 2 lakes, estuaries, and wetlands. Several of these impaired water bodies are located within the CD watersheds.

The six reservoirs in the CD watersheds provide over a billion gallons of water daily to New York City and other nearby communities. Therefore, the 303d listing of all six of these reservoirs for phosphorous or pathogen impairment is of particular concern to people living within New York City. Potential sources of impairment are municipal treatment plant effluent, stream bank erosion, and urban and agricultural runoff.

Most drinking water sources require filtration and treatment with chlorine before public consumption is allowed. New York City drinking water supplied by the older Croton water supply system currently requires filtering (Figure 1.3). According to the EPA, urban development and higher growth rates in the Croton watersheds would overwhelm any watershed management options for protecting the drinking water coming from its reservoirs (Brown, 2000). However, water coming from the CD water supply reservoirs, which supply 90% of New York City's drinking water, is currently under an exemption granted by an EPA filtration avoidance determination (FAD; Brown, 2000). The FAD is a conditional exemption from having to build a filtration plant required by the federal government.

In order to avoid filtration in the future, the city must implement a series of watershed protection measures aimed at preserving water quality in the CD watersheds. In 1997 a watershed Memorandum of Agreement (MOA) negotiated by the local communities, New York City, New York State, environmental groups, and the EPA was signed. The MOA lays out a series of plans for preserving high quality drinking water. These plans include upgrading current sewage treatment plants, implementing new watershed regulations, designing a potential filtration system, and acquiring critical lands (MOA, 1997).

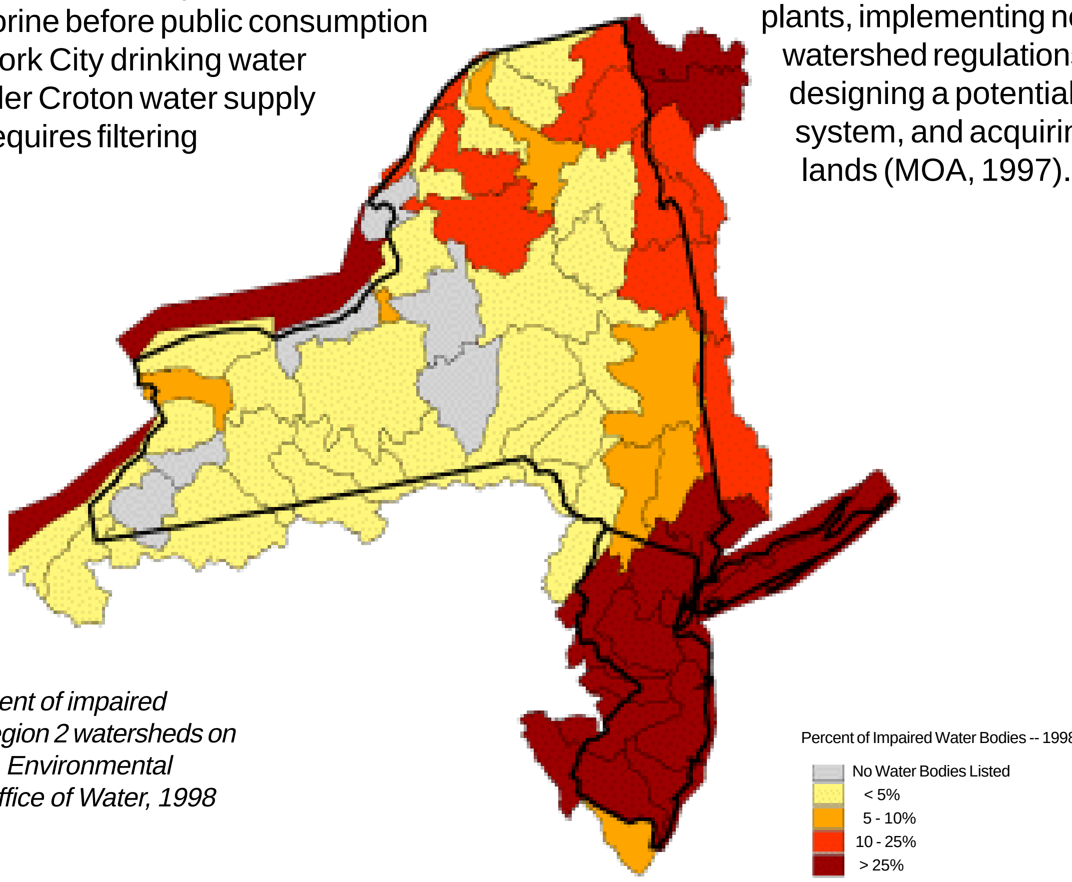


Figure 1.2. *The percent of impaired waterbodies within Region 2 watersheds on the 303d list. Source: Environmental Protection Agency, Office of Water, 1998 State 303d listings.*

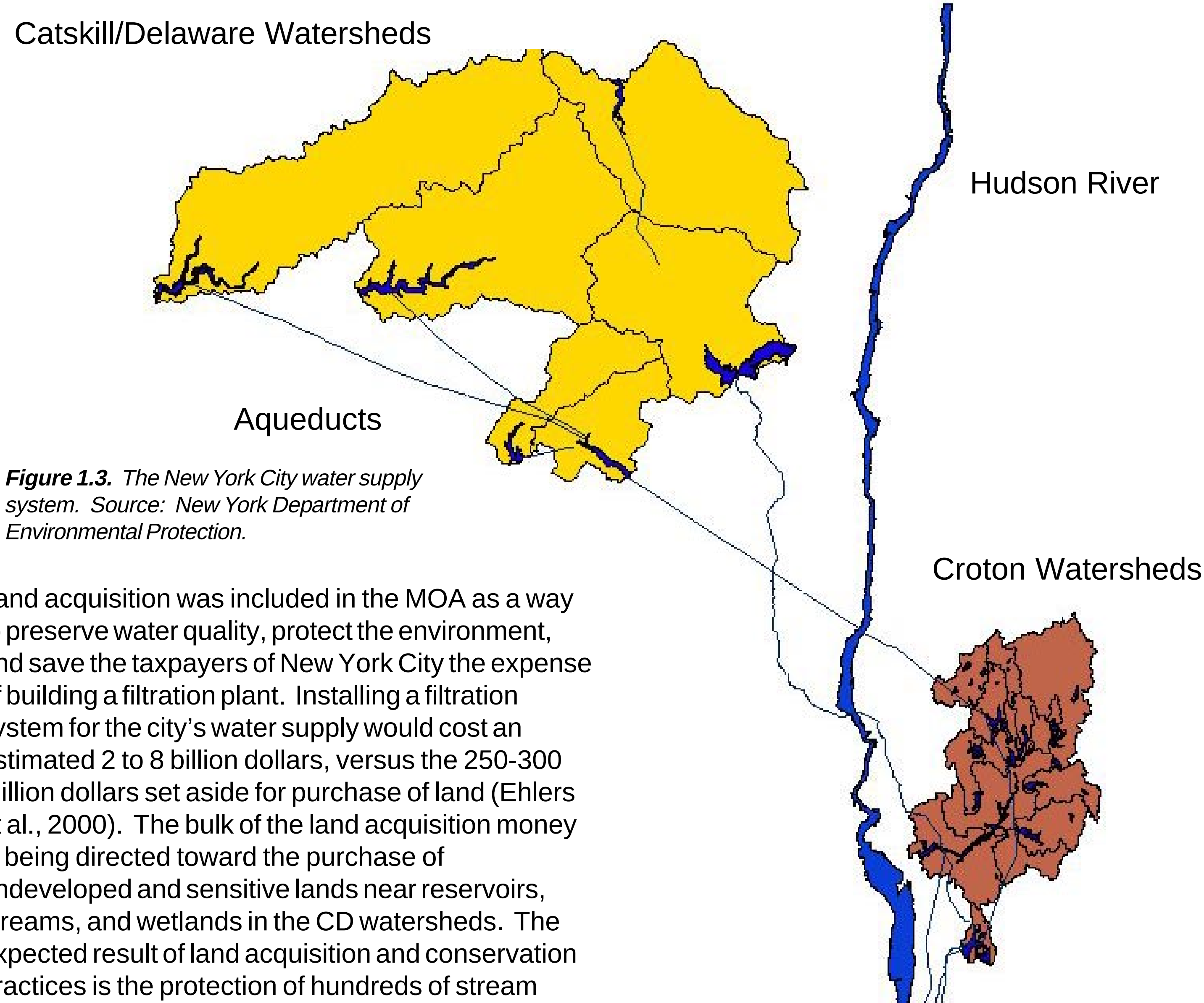


Figure 1.3. *The New York City water supply system. Source: New York Department of Environmental Protection.*

Land acquisition was included in the MOA as a way to preserve water quality, protect the environment, and save the taxpayers of New York City the expense of building a filtration plant. Installing a filtration system for the city's water supply would cost an estimated 2 to 8 billion dollars, versus the 250-300 million dollars set aside for purchase of land (Ehlers et al., 2000). The bulk of the land acquisition money is being directed toward the purchase of undeveloped and sensitive lands near reservoirs, streams, and wetlands in the CD watersheds. The expected result of land acquisition and conservation practices is the protection of hundreds of stream miles, the preservation of thousands of acres of natural areas, and continued high water quality without the cost of a multi-billion dollar filtration system.

There have been numerous studies investigating how human use impacts water quality. For example, the contribution of pollution by runoff after a rainfall event can be lowered by increasing riparian buffer forest cover (Correll, 1997). Watersheds with high percentages of bare ground and anthropogenic cover increase runoff energy and decrease delivery time of pollutants to water bodies (Fennessy and Cronk, 1997). In general, previous studies have made use of landscape and water data from a single snapshot in time (e.g., mid-1990s) to establish the influence of the landscape on pathogens and nutrient loads to streams (Jones et al., 2001; Mehaffey et al., 2001). However, they fail to establish any long-term trends. Prior research has also been focused in areas of the country with very different biophysical and land use patterns than those found within Region 2 and the CD watersheds. In this study relationships between landscape and water quality in the CD watersheds are investigated using both snapshots in time and long term trends analyses.

Layout

This chapter describes the report objectives and layout and provides an overview of environmental and water resource concerns within the study area. Chapter 1 is followed by a description of the biophysical setting of the Catskill/Delaware watersheds in Region 2. Chapter 2 is designed to help readers orient themselves by using familiar landmarks such as state boundaries, lakes, and mountain ranges. Chapter 2 also introduces the reader to potentially unfamiliar concepts and terminology in landscape ecology such as topography, land cover, stream connectivity, and watershed. The basic methodology of determining land cover from satellite imagery and assessing its accuracy, the calculations of the landscape metrics, and the procedures used to evaluate the data are set forth in Chapter 3. For further information on methodologies, the reader is referred to the Appendices, List of References, and Books for Interested Readers found at the end of the report. Chapter 4 contains landscape metric maps of Region 2 and CD watersheds. The intent of this chapter is to provide a quick view of how land cover and land use in the CD watersheds ranks when compared to the surrounding region. In addition, this chapter shows how assessments of environmental condition change with watershed size. The reader can observe how the amount and type of information change between the larger regional watersheds and community level subwatersheds.

In the fifth chapter the focus is narrowed to the CD watersheds. This chapter shows the reader the location and amount of landscape change that has occurred during the past two decades. As in the case of the preceding chapters, Chapter 6 gives the reader an idea of how water quality conditions differ across the CD watersheds. Like landscape, water quality condition can vary over time as well as space. Therefore, Chapter 6 presents an evaluation of both spatial and temporal affects on the three water quality measurements. Additional water quality details, data, and graphs are provided in the appendices.

Chapter 7 brings the water quality and landscape data together using a statistical procedure called a stepwise regression. Results from the analyses of 32 subwatersheds are presented so the reader can see which measures of landscape condition are important to water quality. The regression models are then applied to all of the CD water supply area to approximate water quality condition in each of the subwatersheds. In addition to the regression analyses, Chapter 7 provides a table of water quality, land use, and land cover trends over time for those sites used in the regression analyses. In the final chapter (Chapter 8) a synopsis of the results from Chapters 3, 4, 5, 6, and 7 is provided along with a set of recommendations.

This report is meant to provide information that can be used by a wide variety of audiences. In general as readers progress through the chapters they will find that the terminology and analyses become more complex and technical in the later half of the report. However, a summary section is provided at the end of each chapter and the final discussion in Chapter 8 points out relevant findings from the study.

Road construction on State Highway 10 in the town of Bloomville, Cannonsville watershed.

Chapter 2. The Biophysical Setting

This chapter contains an overview of the biophysical setting of Region 2 and the Catskill/Delaware watersheds including topography, soils, streams, watershed boundaries, and land cover. Besides providing a means of orienting the reader and describing the area of study, these biophysical data are necessary for calculating a number of the landscape metrics presented in Chapter 4.

Land Cover and Topography

The mountains, valleys, plateaus, and coastal areas form distinctive physical and biological characteristics within Region 2 (Figure 2.1). The northwest has a lower elevation and is bounded on the north and west by the Great Lakes. Heading east from the banks of the Great Lakes, the terrain rises to the plateaus of central New York. Variations in soil moisture, pH, and cation exchange capacity are related to elevation and other soil physical properties, such as clay and organic contents. Specific topography, elevation, and soil physical and chemical properties dictate the distribution of both natural vegetation and human utilization of the land (Larcher, 1995). The plateaus provide a gently sloping area made up of high organic matter glacial till soils, well suited for the cultivation of crops and urban development (Figure 2.2). To the northeast and southeast of the plateau, elevation rises, culminating in the Adirondack and Catskill Mountains, respectively. The low organic matter soils of the Adirondack and Catskill mountain ranges make them less desirable for agricultural use (Figure 2.3a). Left relatively undisturbed by humans, the high elevation areas within Region 2 contain the northern hardwood forest with its distinctive maple, birch, beech, and hemlock trees. The CD watersheds lie within the plateau and Catskill Mountains and are part of both the Delaware and Hudson river basins.

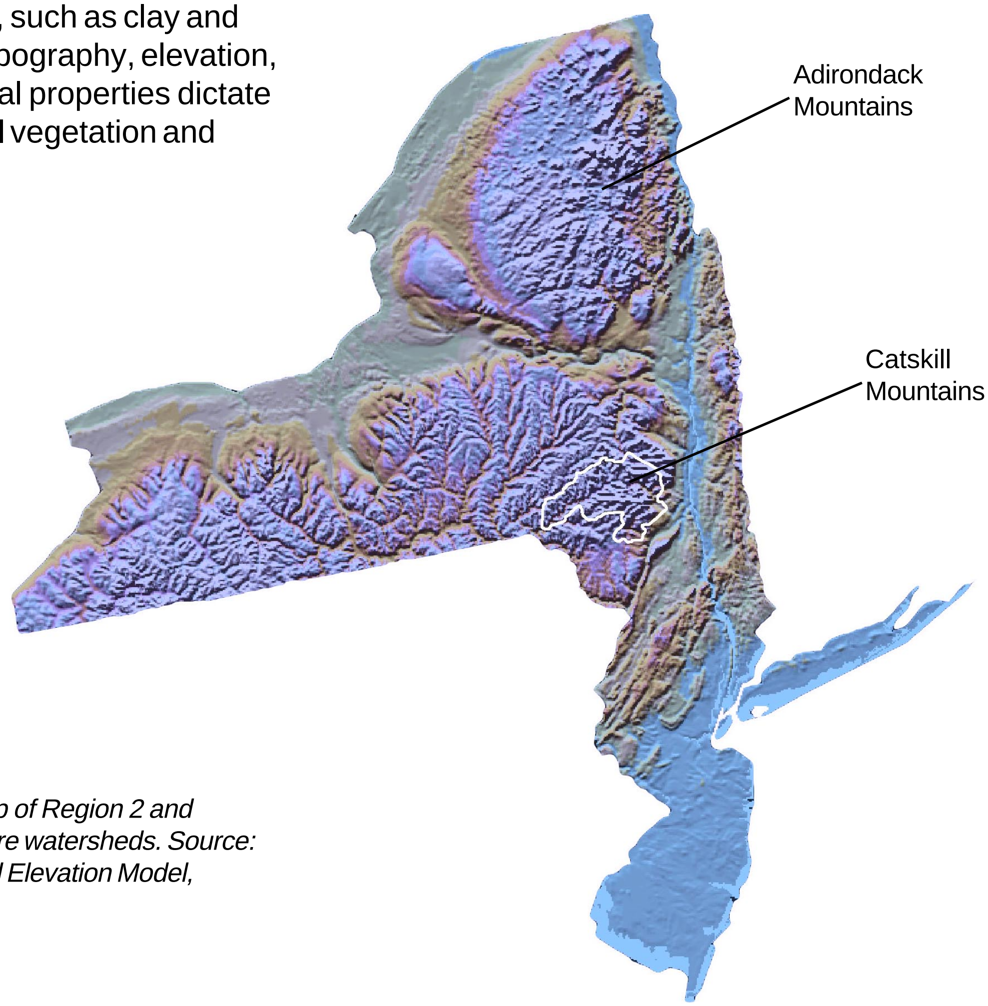


Figure 2.1. *Shaded relief map of Region 2 and location of the Catskill/Delaware watersheds. Source: U.S. Geological Survey, Digital Elevation Model, 1:24,000 scale.*

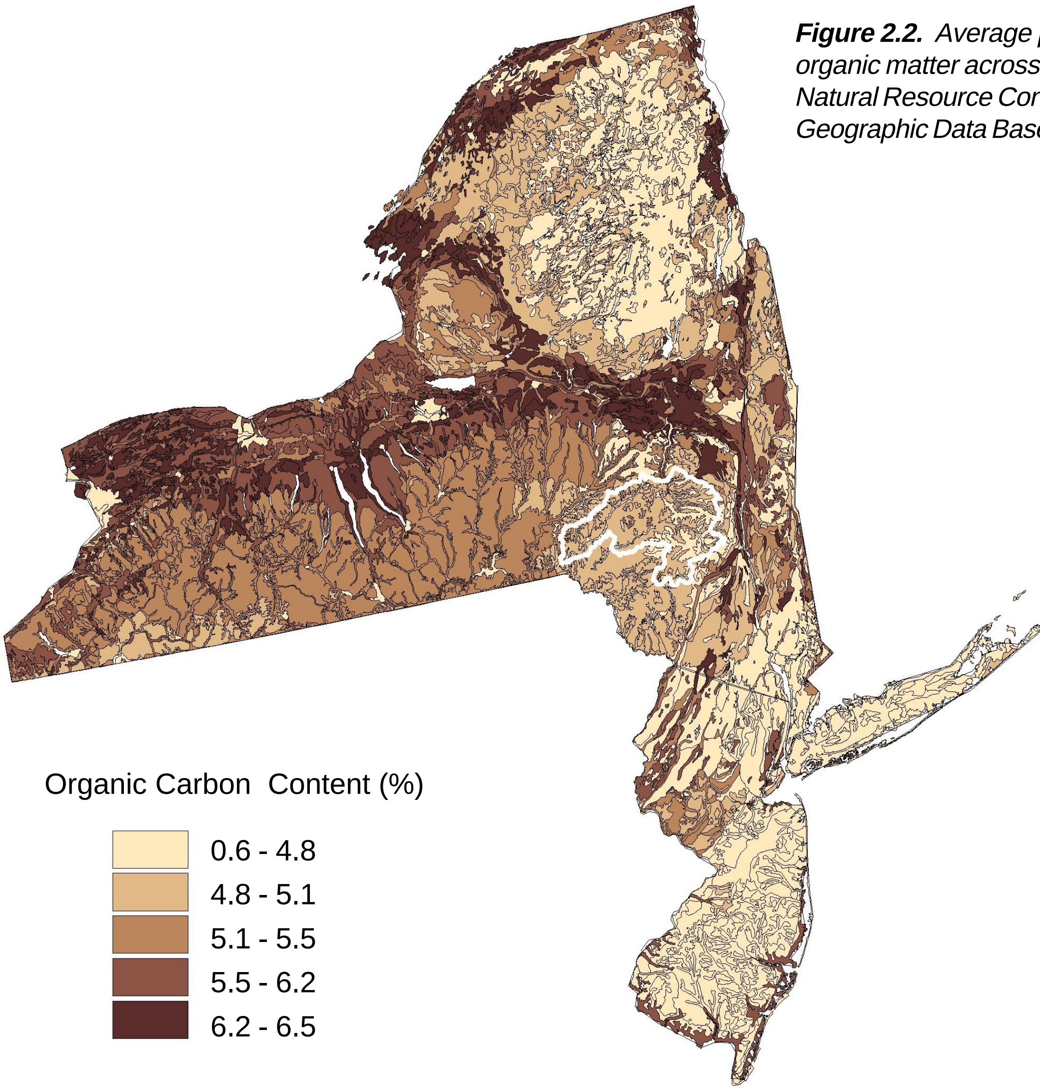


Figure 2.2. *Average percent soil total organic matter across Region 2. Source: Natural Resource Conservation, State Soil Geographic Data Base.*

The 4,100 km^2 (1,583 mi^2) CD watersheds are located in the southeast corner of New York State, 160 km (~100 mi) northwest of New York City. Historically, the CD watersheds were dominated by northern hardwood forest, much of which was logged prior to the mid-1800s (van Valkenburg, 1996). The transfer of ownership of 14,000 ha (~34,600 acres) of forest land back to New York State in 1884 was the starting point for the development of the Catskill Park. In the decades since the park's inception the forest has rebounded from its previous losses and now consists of a mixture of hardwood, deciduous, and evergreen trees covering 285,507 ha (705,500 acres). The extensive forest cover in the CD watersheds reflects the benefit of the park's presence and relatively low human use (Figure 2.3b). The greatest amount of human use such as (1) agriculture (row crop and pasture), (2) bare ground (ski areas, fallow fields, and quarries), and (3) development (low intensity residential, golf courses, and lawns) occurs in the northwestern CD watersheds.

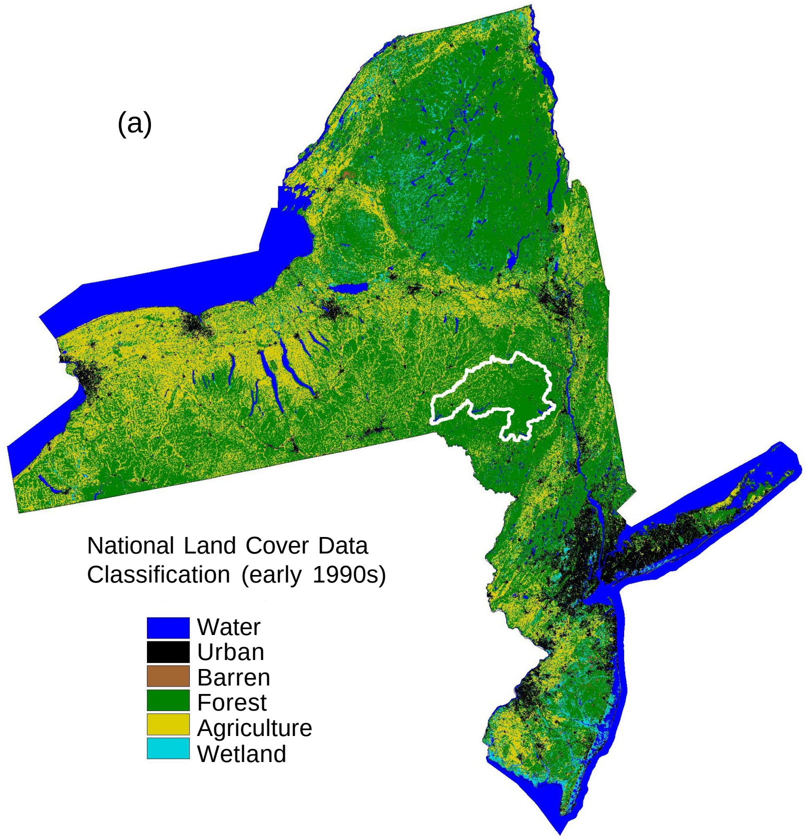
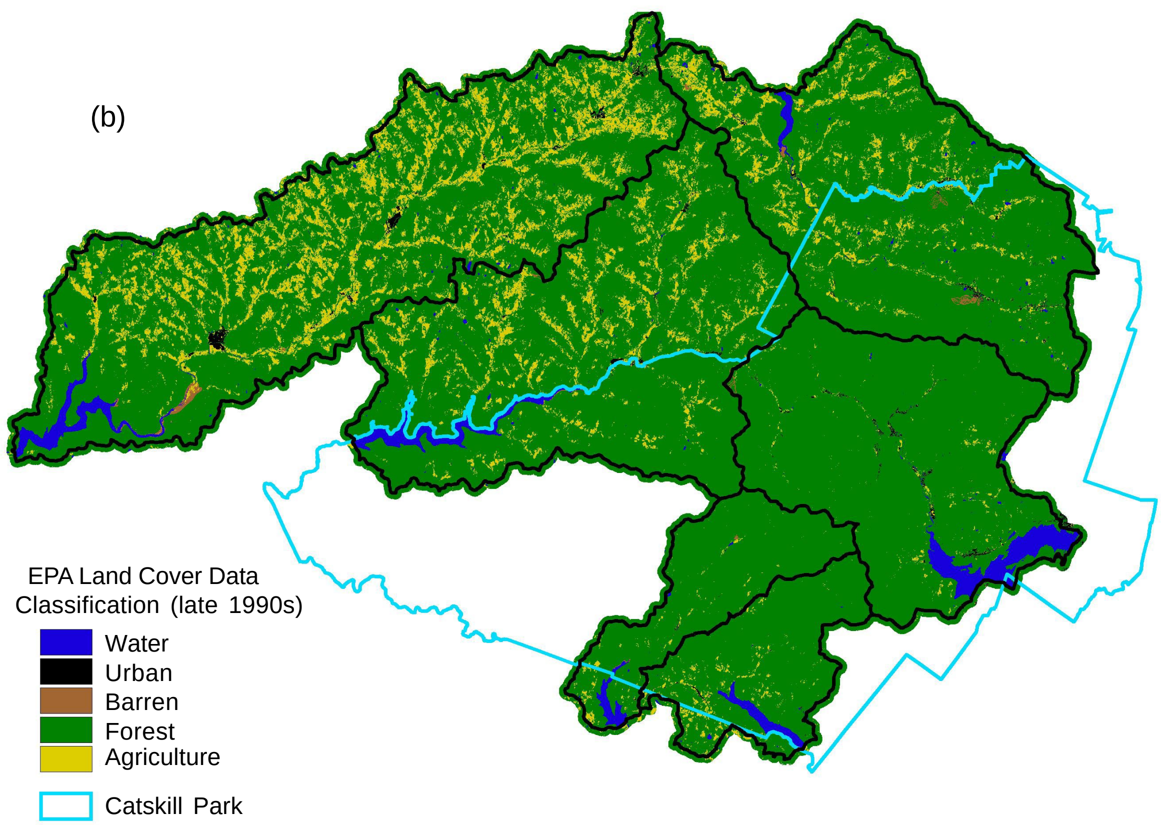


Figure 2.3. *Land cover/use in **(a)** Region 2 and **(b)** the Catskill/Delaware watersheds. Sources: Source:Multi-Resolution Land Characteristics (MRLC) Program, derived from Landsat Thematic Mapper (TM) data, 30-m resolution and the Environmental Protection Agency, Landscape Ecology Branch, derived from Landsat Thematic Mapper (TM) data, 30-m resolution.*



The topography of the CD water supply area is diverse and except for the Adirondacks to the north has the greatest elevation in New York State (Figure 2.4). The area is divided into two main water supply systems -- the Delaware (Cannonsville, Pepacton, Neversink and Rondout watersheds) and the Catskill (Ashokan and Schoharie watersheds). The watersheds which feed the Cannonsville and Pepacton reservoirs are located at the southeastern edge of New York State's central plateau region and have a gently rolling landscape. Glacial till dominates their geology, making large portions of the Cannonsville and Pepacton watersheds suitable for agriculture (Miller, 1970). The Ashokan and Schoharie watersheds are within the Catskill Mountains and the Rondout and Neversink at the mountains southern edge. These four watersheds are more rugged with shallow soils (1 m or ~3 ft) and large portions of exposed bedrock.

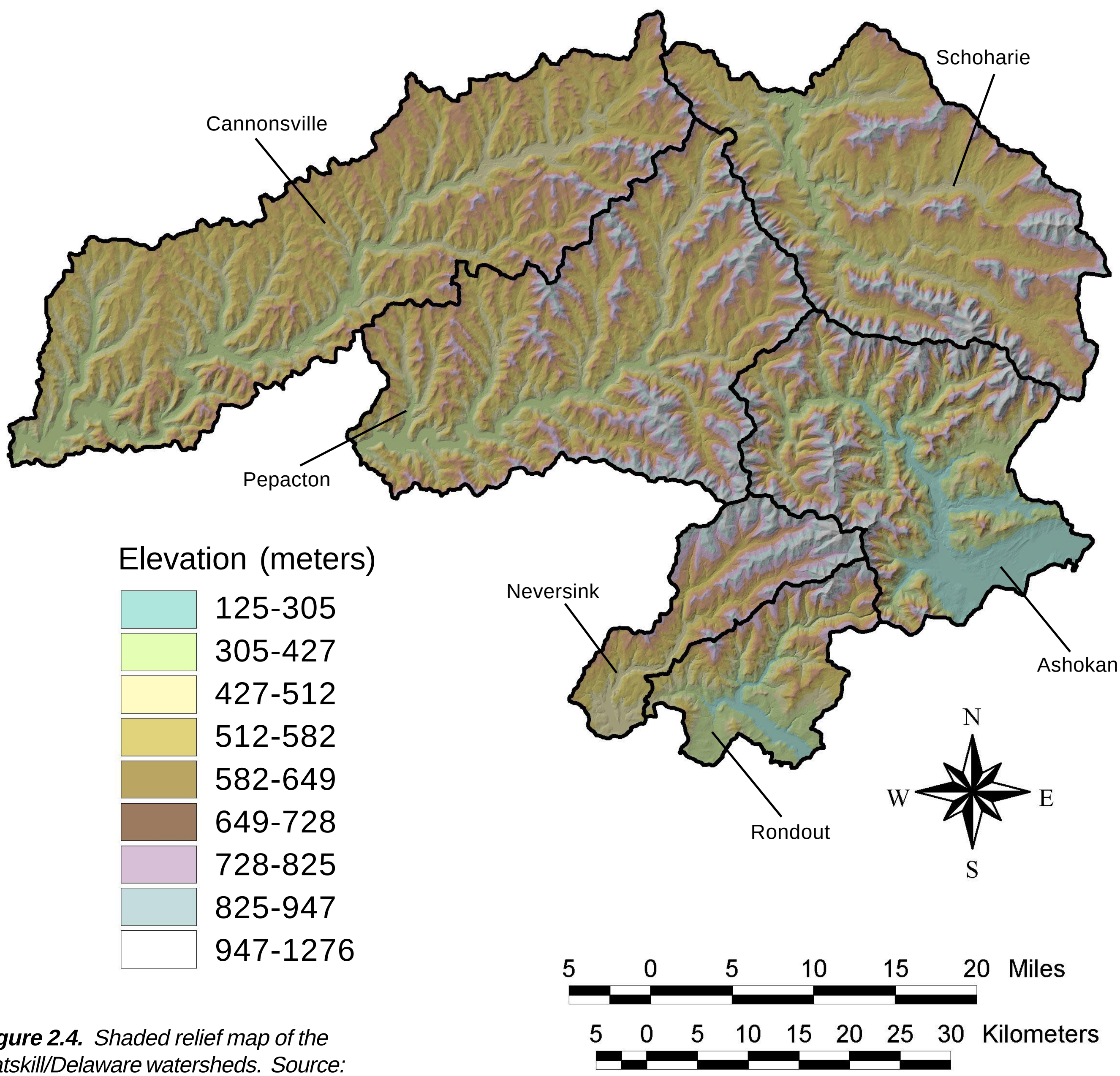


Figure 2.4. *Shaded relief map of the Catskill/Delaware watersheds. Source: U.S. Geological Survey, Digital Elevation Model, 10-m.*

Streams

Streams and rivers direct the flow of water across the landscape and are a dominant feature of Region 2. They provide necessary resources to plants, nearby riparian habitat and wildlife, and humans (Petts, 1994). In the past, city life and commerce had a more direct connection to the rivers, resulting in many of the Nation's cities being located on or near major rivers. Today, streams and rivers continue to play an important role as a source of drinking water, irrigation, recreation, and transportation. The landscape surrounding the streams and rivers provides a system rich in diversity and productivity of plant and animal species. At the same time, these areas are recognized as a primary resource for human use. The result is a conflict between agricultural and urban development and the need for a healthy, diverse, and stable system. The stream networks contributing to or receiving contributions from the CD watersheds can be seen in the EPA River Reach File (RF3) map, which is derived from the U.S. Geological Survey (USGS) Digital Line Graph - streams at a scale of 1:100,000 (Figure 2.5).

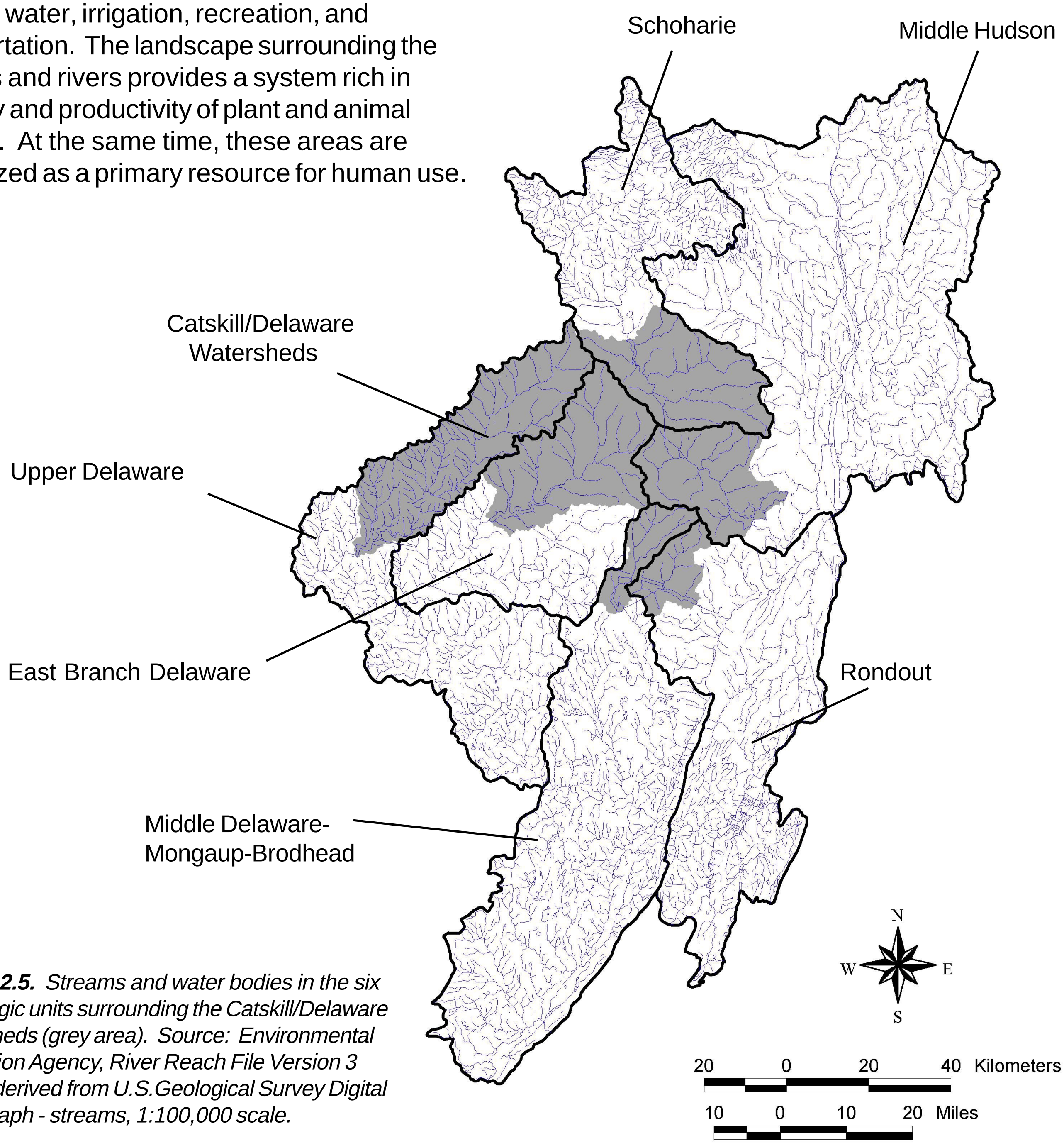


***Figure 2.5.** Streams and water bodies in the six hydrologic units surrounding the Catskill/Delaware watersheds (grey area). Source: Environmental Protection Agency, River Reach File Version 3 (RF3), derived from U.S.Geological Survey Digital Line Graph - streams, 1:100,000 scale.*

The flow and drainage of streams in the CD watersheds split the area into six large contributing areas with reservoirs as end points. The streams and reservoirs of the CD watersheds in turn are connected to three larger river basins. The Cannonsville, Pepacton, and Neversink watersheds all lie within the upper, middle and east Delaware hydrologic units, Rondout watershed within the Rondout hydrologic unit, Ashokan watershed within the Middle Hudson hydrologic unit, and Schoharie watershed within the Schoharie hydrologic unit (Figure 2.5).

The stream map, developed by the New York City Department of Environmental Protection (NYCDEP) using USGS 1:24,000 quads, shows the prominent streams feeding the CD water supply reservoirs, including the East and West Delaware, Esopus, Neversink, Rondout and Schoharie (Figure 2.6). The difference in stream density between the Region 2 RF3 and the NYCDEP stream map is due to an increase in resolution (i.e., 1:100,000 and 1:24,000).

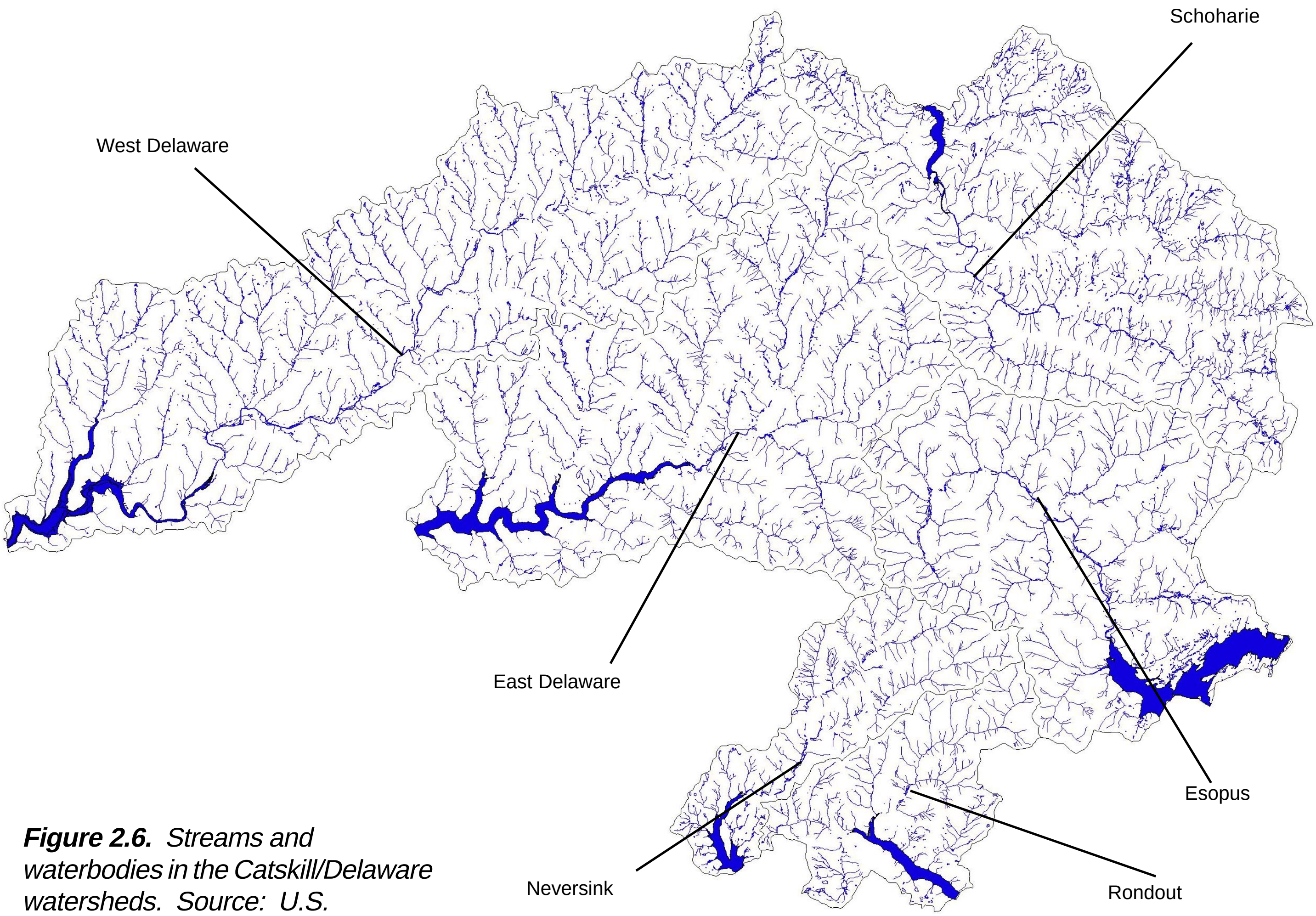


Figure 2.6. *Streams and waterbodies in the Catskill/Delaware watersheds. Source: U.S. Geological Survey 1:24,000 scale, modified by New York City Department of Environmental Protection.*

Watersheds

A watershed is a natural unit of land that captures rainfall, snow, or other forms of precipitation which drain or infiltrate to streams and ground water. The amount of water entering and leaving a watershed plays a crucial role in defining characteristics and change within an ecosystem. Therefore, a watershed provides a limited and contained unit of measure for evaluating landscape and water relations (Aber and Melillo, 1991). A hydrologic unit (HUC) represents all or part of a surface drainage area, a combination of drainage areas, or a distinct hydrologic feature. A subset of USGS national eight-digit hydrologic cataloging units is used to summarize landscape metrics for Region 2 (Figure 2.7; Table 2.1).

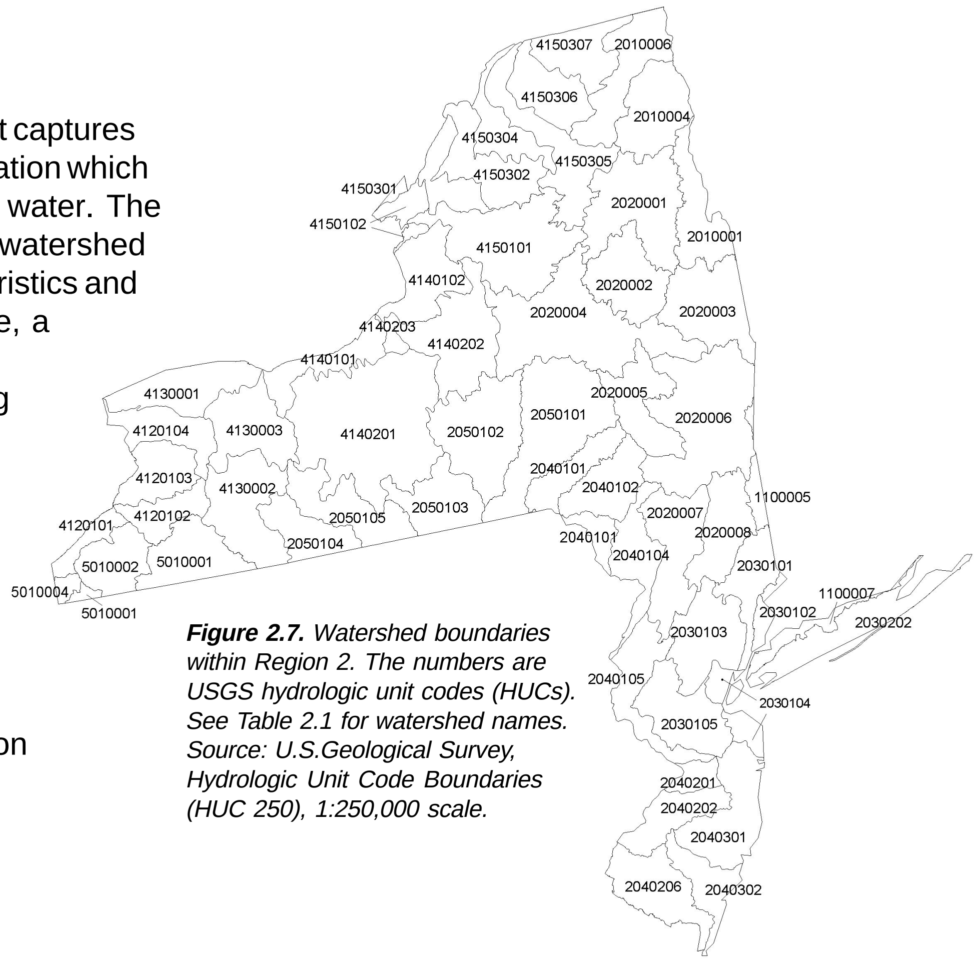


Figure 2.7. *Watershed boundaries within Region 2. The numbers are USGS hydrologic unit codes (HUCs). See Table 2.1 for watershed names. Source: U.S.Geological Survey, Hydrologic Unit Code Boundaries (HUC 250), 1:250,000 scale.*

Table 2.1. Regional Hydrologic Unit Code Numbers and Names (HUCs in blue surround the Catskill/Delaware watersheds).

1100005	Housatonic	2050101	Upper Susquehanna
1100006	Saugatuck	2050102	Chenango
1100007	Long Island Sound	2050103	Owego-Wappasening
2010001	Lake George	2050104	Tioga
2010004	Ausable	2050105	Chemung
2010006	Great Chazy-Saranac	4120101	Chautauqua-Conneaut
2020001	Upper Hudson	4120102	Cattaraugus
2020002	Sacandaga	4120103	Buffalo-Eighteenmile
2020003	Hudson-Hoosic	4120104	Niagara
2020004	Mohawk	4130001	Oak Orchard-Twelvemile
2020005	Schoharie	4130002	Upper Genesee
2020006	Middle Hudson	4130003	Lower Genesee
2020007	Rondout	4140101	Irondequoit-Ninemile
2020008	Hudson-Wappinger	4140102	Salmon-Sandy
2030101	Lower Hudson	4140201	Seneca
2030102	Bronx	4140202	Oneida
2030103	Hackensack-Passaic	4140203	Oswego
2030104	Sandy Hook-Staten Island	4150101	Black
2030105	Raritan	4150102	Chaumont-Perch
2030202	Southern Long Island	4150301	Upper St. Lawrence
2040101	Upper Delaware	4150302	Oswegatchie
2040102	East Branch Delaware	4150303	Indian
2040104	Middle Delaware-Mongaup-Brodhead	4150304	Grass
2040105	Middle Delaware-Musconetcong	4150305	Raquette
2040201	Crosswicks-Neshaminy	4150306	St. Regis
2040202	Lower Delaware	4150307	English-Salmon
2040206	Cohansey-Maurice	5010001	Upper Allegheny
2040301	Mullica-Toms	5010002	Conewango
2040302	Great Egg Harbor	5010004	French

Source: U.S.Geological Survey, Hydrologic Unit Code Names and Numbers (HUC 250), 1:250,000 scale.

The HUCs are fairly consistent in size across the country making comparisons of land cover between different regions possible. However, the map of HUCs within New York and New Jersey illustrates one of the problems with using naturally defined units such as watersheds to assess conditions within state boundaries. The HUCs which cross state lines are divided and therefore metrics calculated for these partial watersheds may not accurately represent the watershed system as a whole.

A separate group of GIS-delineated watersheds was used for the CD watersheds. These watersheds were created using elevation to determine boundaries or ridge tops which divide water flow to a main drainage point (stream, river, or water body). The watersheds consist of six drainage areas, each ending in a manmade reservoir, and 79 subwatersheds developed by NYCDEP from 30-m digital elevation models (DEM; Figure 2.8; Table 2.2). These NYCDEP watersheds were used in conjunction with land cover data to conduct the landscape assessment presented in Chapter 4.

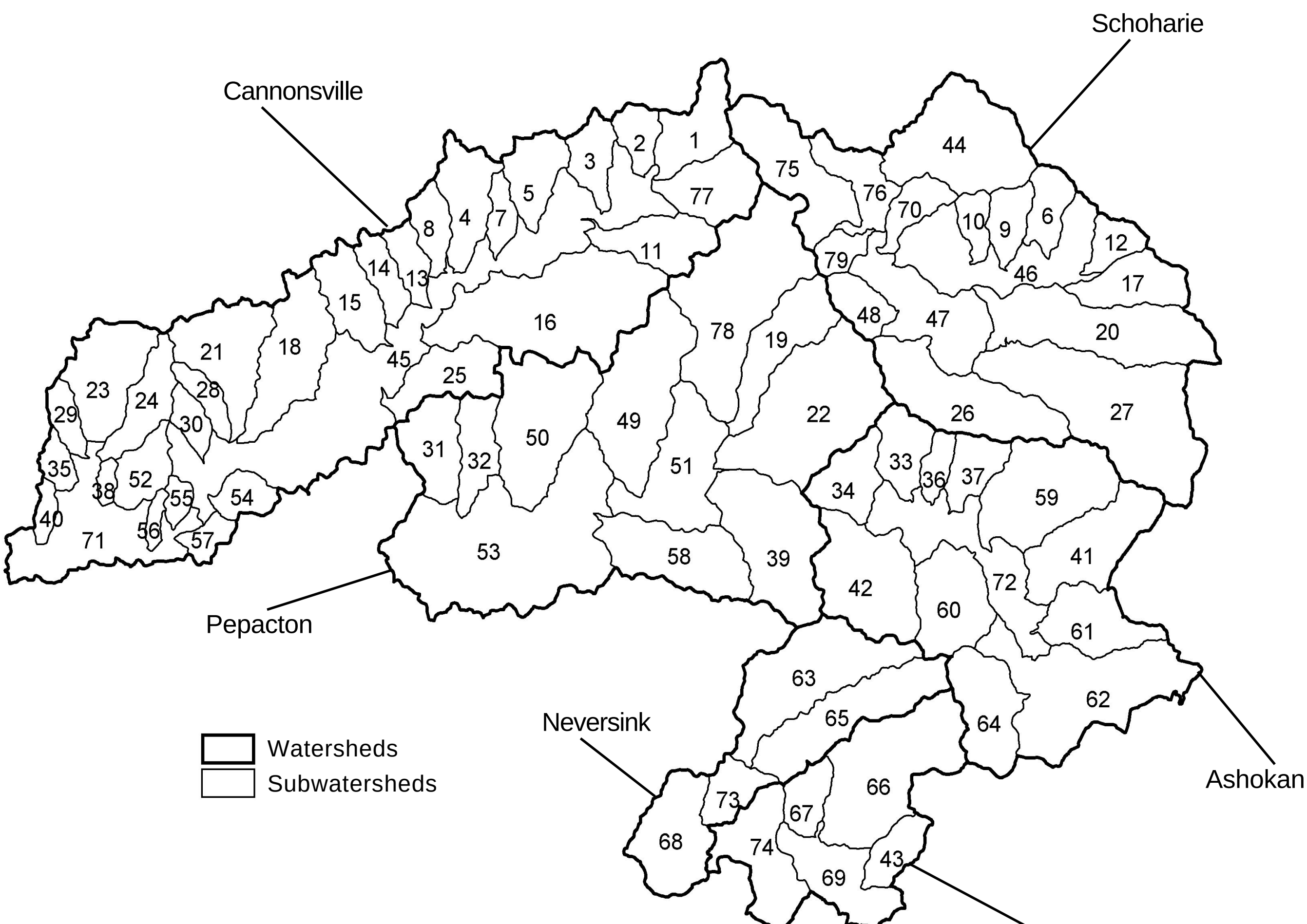


Figure 2.8. Catskill/Delaware watersheds and subwatersheds. Numbers correspond to subwatershed names in Table 2.2. Source: New York City Department of Environmental Protection created from U.S. Geological Survey, Digital Elevation model, 30-m data.

Table 2.2. Catskill/Delaware Subwatershed Names with Numbers Corresponding to Figure 2.8

1	West Branch Delaware Headwaters	41	Beaver Kill
2	Lake Brook	42	Esopus Creek Headwaters
3	Betty Brook	43	Trout Creek - Rondout
4	Elk Creek	44	Manor Kill
5	Wright Brook	45	West Branch Delaware River
6	Mitchell Hollow	46	Batavia Kill - Schoharie
7	Kidd Brook	47	Schoharie Creek
8	Falls Creek	48	Little West Kill
9	North Settlement	49	Platte Kill
10	Sutton Hollow	50	Tremper Kill
11	Rose Brook	51	East Branch Delaware River
12	Silver Lake	52	Dryden Brook
13	Steele Brook	53	Pepacton Reservoir
14	Peaks Brook	54	Beers Brook
15	Platner Brook	55	Wakeman Brook
16	Little Delaware River	56	Fish Brook
17	Batavia Kill Headwaters	57	Chase Brook
18	East Brook	58	Mill Brook
19	Batavia Kill - Pepacton	59	Stony Clove Creek
20	East Kill	60	Woodland Creek
21	West Brook	61	Little Beaverkill
22	Bush Kill_Pepacton	62	Ashokan Reservoir
23	Trout Creek_Cannonsville	63	West Branch Neversink River
24	Loomis Brook	64	Bush Kill - Ashokan
25	Bagley Brook	65	East Branch Neversink River
26	West Kill	66	Rondout Creek
27	Schoharie Creek Headwaters	67	Sugarloaf Brook
28	Third Brook	68	Neversink Reservoir
29	Sherruck Brook	69	Rondout Reservoir
30	Pines Brook	70	Huntersfield Creek
31	Terry Clove (Bryden Hill)	71	Cannonsville Reservoir
32	Fall Clove (Brydon Lake)	72	Esopus Creek
33	Bushnellsville Creek	73	Neversink River
34	Birch Creek	74	Chestnut Creek
35	Dry Brook - Cannonsville	75	Bear Kill
36	Peck Hollow	76	Schoharie Reservoir
37	Broadstreet Hollow	77	Town Brook
38	Chamberlain Brook	78	East Branch Delaware Headwaters
39	Dry Brook - Pepacton	79	Johnson Hollow Brook
40	Johnny Brook		

Chapter 3. Methodology

This chapter discusses the various data sources and methods used to assess landscape and water quality conditions in Region 2 and CD watersheds. The methods in this chapter cover landscape classification, landscape metrics calculation, an EPA-delineation of select subwatersheds, statistical procedures for determining spatial and temporal trends, and relationships between landscape and water quality data. Also included in this chapter is information on data sources and the importance of the three water quality parameters selected for analsysis.

Regional Classification

The Region 2 land cover data are based primarily on images taken in the early 1990s by the Landsat satellite (Thematic Mapper; TM). Different surfaces reflect different amounts of light at various wavelengths; therefore, it is possible to classify land cover types from satellite measurements of reflected light (Figure 3.1; Lillesand and Kieffer, 1994). Regional land cover maps of data are prepared by the Multi-Resolution Land Characteristics (MRLC) Consortium, a multi-agency sponsored mapping program. The land cover data is at a 30-meter resolution. The National Land Cover Data (NLCD) classification for Region 2 consists of 18 land cover classes which, for the purpose of this study, were consolidated into six dominant categories (Table 3.1). Consolidation into six classes also improved the overall accuracy of the land cover classes by eliminating identification error inherent in interpreting satellite imagery. For example, the identification of forest cover is fairly straight forward. However, splitting the forest into subsets of hand-planted evergreen, orchard, and decidous trees, and forested wetlands increases the possiblility for classification error.

Figure 3.1. *Illustration of differential light reflectance properties for sediments suspended in water and land surfaces over a portion of Long Island Sound. These images can be manipulated in various ways to extract information about the Earth's surface. Source: North American Landscape Characterization Program.*

Table 3.1. Aggregation of the National Land Cover Data (NLCD) Regional Land Cover Classes

NLCD Class	Aggregated Class
Open Water	Water
Low Intensity Residential	
High Intensity Residential	
High Intensity Commercial	Urban
Cultivated	
Pasture	
Row Crops	
Small Grains	
Urban Grass	Agriculture
Deciduous Forest	
Evergreen Forest	
Mixed Forest	Forest
Bare Rock	
Quarries	
Transitional	
Bare Soil	Barren
Woody Wetland	
Emergent Wetland	Wetland

Catskill/Delaware Classification

To evaluate landscape condition and change in the CD water supply watersheds, land cover data sets were produced for four time periods: 1975, 1985, 1991, and 1998. The EPA Landscape Ecology Branch and Lockheed Martin Environmental Services jointly prepared the CD land cover data. The mid-1970s classification has a spatial resolution of 60 m (Landsat multispectral scanner; MSS); however, the mid-1980s, early-1990s, and late-1990s classifications have a spatial resolution of 30 m (Landsat TM). The data from each image were grouped into one of five categories: water, forest, agriculture, urban, and bare ground. Wetlands were exclude due to their minimal presence in the area and the inability to accurately classify them without extensive ground truthing. The classifications were assessed to have an overall accuracy near 90%. The accuracy assessment was conducted by the EPA Landscape Ecology Branch Environmental Photographic Interpretation Center (LEB-EPIC) in Reston, Virginia. A more detailed description of the classification technique and accuracy assessment can be found in Appendix A.

EPA-Delineated Subwatersheds

A second set of CD subwatersheds, delineated by the EPA Landscape Ecology Branch, was used for assessing relationships between the landscape and water quality. Unlike the NYCDEP subwatersheds shown in Figure 2.8, the 32 EPA watersheds are based on modeling flow accumulation to a select set of water sampling locations using 10-m DEMs (Figure 3.2; more detailed information can be found in Appendix A). For landscape and water quality relationship analyses, the sampling sites had to be located off main stream tributaries or at headwaters and have no nearby upstream sewage treatment plant. Half of the 32 EPA-delineated subwatersheds match the NYCDEP boundaries, but the remaining half are either smaller or larger in size.

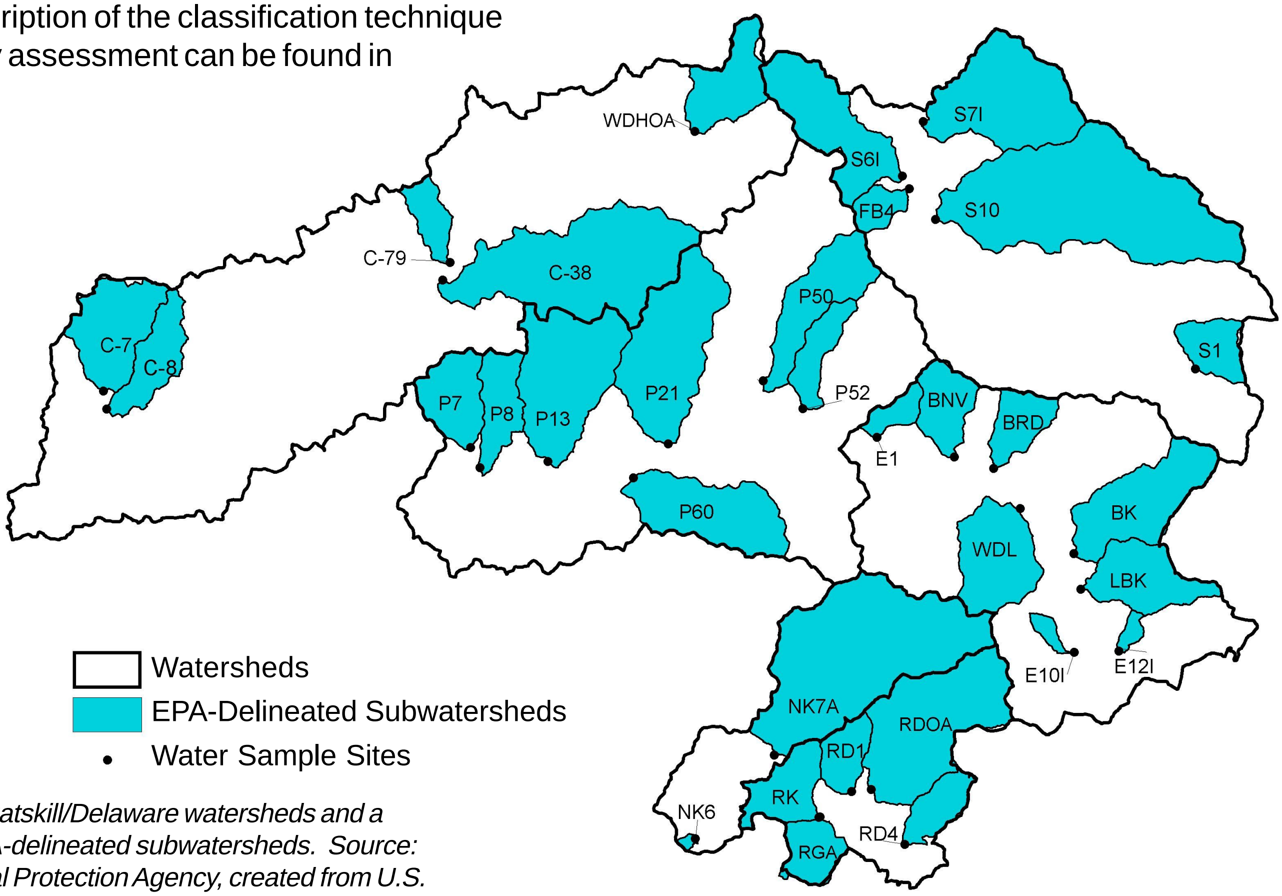


Figure 3.2. *Catskill/Delaware watersheds and a subset of EPA-delineated subwatersheds. Source: Environmental Protection Agency, created from U.S. Geological Survey, Digital Elevation model, 10-m data.*

Landscape Metrics

Landscape metrics are defined as measurements that describe the condition of an ecosystem or one of its critical components (O'Neill et al., 1992). The primary uses of a metric are to characterize current status and to track or predict significant change in environmental conditions (Hunsaker et al., 1996). Calculation of these metrics requires the aid of a geographical information system (GIS). Two GIS techniques mentioned in this report include overlaying and clipping (ESRI, 1992). These methods combine two or more data themes to extract a new set of information. For example, by placing a watershed boundary on top of a land cover map, the proportion of a specific land use within a watershed can be determined (Figure 3.3). Land cover change was determined by comparing land cover maps from two different dates on a pixel-by-pixel basis. Landscape change metrics were then determined based on the differences between the maps using the previously mentioned overlaying and clipping techniques.

Once the metrics were calculated, maps showing the relative ranking of watersheds or subwatersheds to each other were produced (Figure 3.4a and b). The watersheds or subwatersheds were ranked by equal interval value ranges for a given landscape metric. All watersheds or subwatersheds within the same data range were colored with one of five colors to represent least (green) to most (red) altered environmental condition. The interval should be read as 60 through 75, 75.01 to 80, and etc. These types of maps, based on ranking, are useful for comparing relative conditions across the Region 2 watersheds and the CD subwatersheds, but are not meant to give details about specific locations. More information on individual metrics discussed in this report are located in Appendix A, and a fuller definition of landscape metrics can be found in the "Mid-Atlantic Atlas" (Jones et al., 1997). The landscape metric maps are presented in Chapter 4 and landscape change maps in Chapter 5.

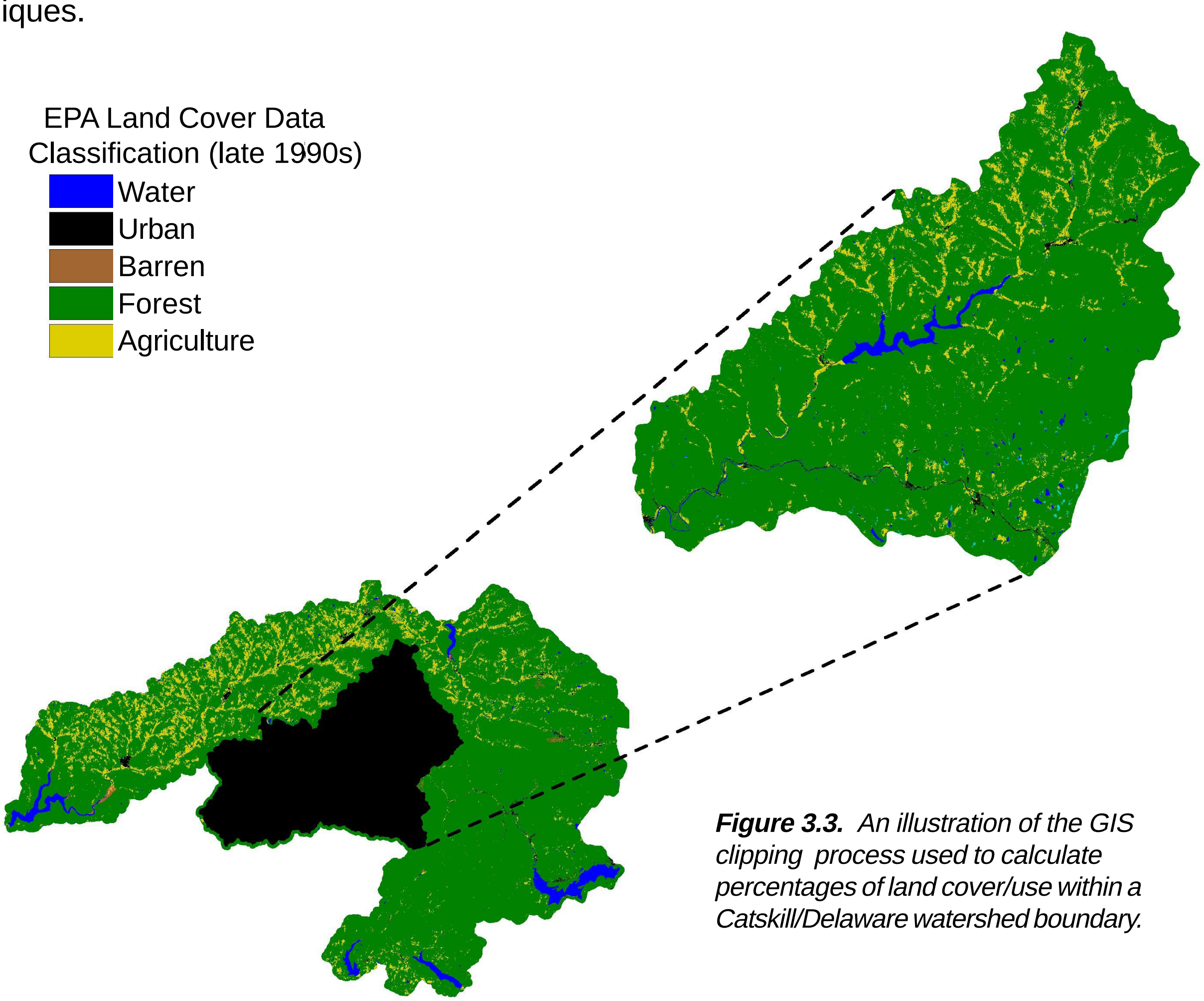
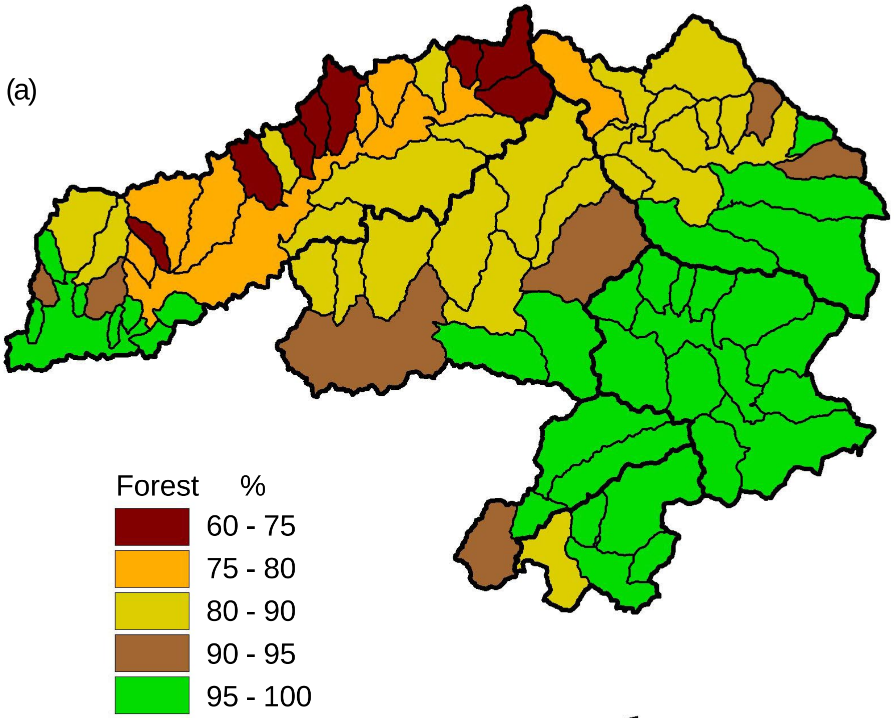


Figure 3.3. *An illustration of the GIS clipping process used to calculate percentages of land cover/use within a Catskill/Delaware watershed boundary.*

(a)



(b)

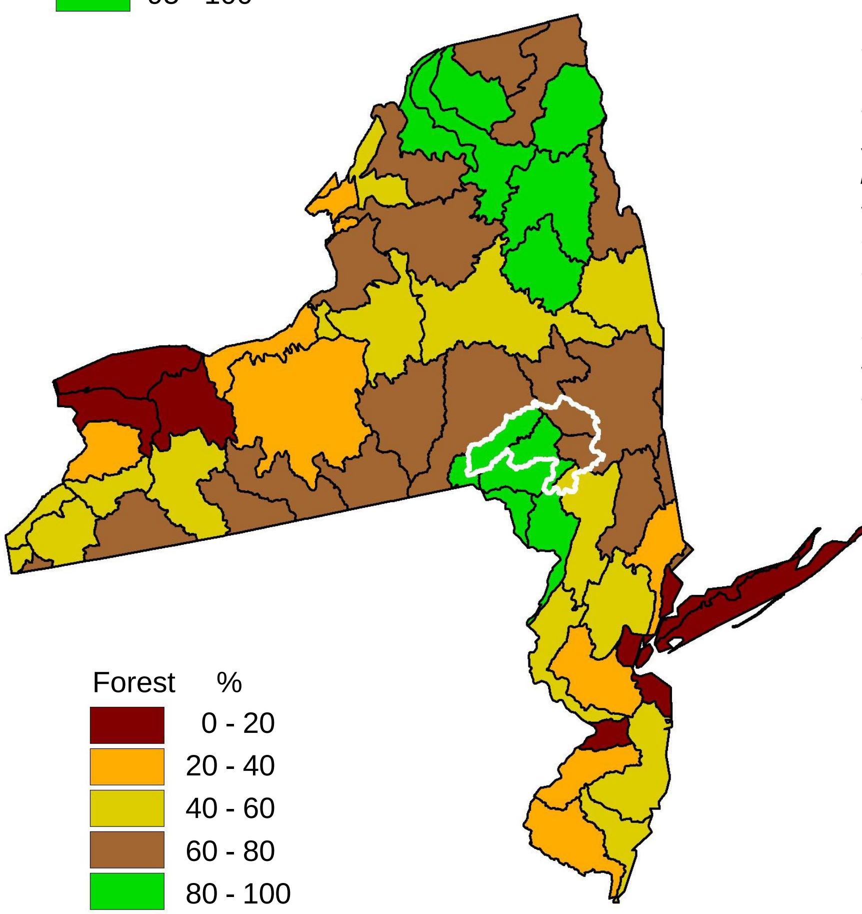


Figure 3.4. *An illustration of the maps that appear in the following report. The maps were color coded to show land cover/use percentages in the* ***(a)*** *Catskill/Delaware subwatersheds and* ***(b)*** *Region 2 watersheds. The effect of scale can be seen in the differences between the Catskill/Delaware subwatershed and regional watershed maps. A greater amount of information is provided by using the smaller subwatershed size. The map colors range from green to red, respectively indicating least to most altered environmental condition. The ranking is relative to the watersheds or subwatersheds within the study area.The interval should be read as 60 through 75, 75.01 to 80, and etc.*

Surface Water Quality Measurements

The NYCDEP monitors the water supply on behalf of the millions of city and state residents who use close to 3.8 billion liters (1 billion gallons) daily. The monitoring program includes numerous sampling stations within the many streams and reservoirs of the CD watersheds (NYCDEP, 1997a). Water quality data have been collected since the early 1900s at a number of these sampling stations, but only the most recent data is available in digital format. The database made available for this study from the NYCDEP contains biweekly surface water measurements from 1987 to 1998. Three water quality variables (total nitrogen, total phosphorus, and fecal coliform bacteria) were chosen for study based on regional and local concerns and on their relationship to landscape condition. Total phosphorous and total nitrogen are measured on grab samples. Fecal coliform bacteria are measured by placing water from a grab sample on a cultural medium and counting the number of colonies present following incubation (NYCDEP, 1997a).

Nitrogen and phosphorus are two essential nutrients required by terrestrial and aquatic organisms. These nutrients enter the water from both natural and human sources. Natural sources of these materials include the soil, animal waste, organic decay, and biologic conversion by bacteria. Human sources include nonpoint runoff of fertilizer and point source effluent inputs. At lower levels nutrients pose a minimal threat to human and aquatic health. However, anthropogenic inputs of nitrogen and phosphorous can raise nutrient concentrations to levels where consumption can result in potential health risks such as "blue baby" syndrome in infants (EPA, 1998b). Acceptable water standards established by New York and EPA are shown in Table 3.2. In addition to health risks, human-induced increases in nutrient levels speed up the natural process of stream and lake eutrophication, resulting in undesirable algal blooms. Excessive algal growth disrupts stream habitat, decreases oxygen availability, and raises turbidity, odor, and color to

Table 3.2. Drinking and Ambient Water Quality Standards for Nitrogen, Phosphorus, and Fecal Coliform Bacteria

	Drinking Water		Ambient Water	
Variable	EPA	NY State*	EPA	NY State
Nitrogen (mg/L)			0.7 **	"Not in an amount allowing growth of algea, weeds and slimes that will impair water for best use."
Nitrate	10	10		
Nitrite	1	1		
Nitrate+Nitrite	10	10		
Phosphorus (mg/L)	N/A	N/A	0.1	"Not in an amount allowing growth of algea, weeds and slimes that will impair water for best use."
Fecal Coliform Bacteria (CFU/100ml/month)	Zero	Zero	~ 200	200 - 2000

* = New York State Department of Health sets drinking water standards; New York State Department of Environmental Conservation sets ambient water quality standards

** = Ambient nitrogen standards have not yet been developed by EPA; the standard is general and based on a ratio of 7:1 (N:P) accepted as optimal for growth of aquatic plants.

unacceptable levels (Harris,1997). When plants and algae die their remains gradually sink and are consumed by aerobic bacteria. Gradually oxygen levels decrease and the water becomes anoxic. Under these conditions anaerobic bacteria flourish producing foul-smelling compounds such as hydrogen sulphide and ammonia. The process of algal bloom and decay can also result in an increase in disinfection by-products as greater amounts of organic carbon interact with chlorine.

Fecal coliforms are bacteria which occur naturally in human and animal intestinal tracts. Bacteria can enter streams from surface water runoff, treatment and septic system discharge, recreational use by humans, and use by wildlife and domestic animals (Fisher et al., 2000). When present in the water, fecal coliform bacteria indicate contamination by warm-blooded animal waste. Human health effects are related to other pathogens which may be excreted along with the fecal coliform bacteria, such as bacteria, protozoa, and viruses. These pathogens can cause outbreaks of hepatitis, typhoid fever, dysentery, diarrhea, and cholera.

Data Evaluation

In order to accomplish the following analyses, different groups of sites were used. That is to say sites used for analysis 1 may or may not be used for analyses 2 and 3. A more extensive discussion of the statistical techniques described in this report is presented in Appendix A. Results from the analyses described here are presented in Chapters 6 and 7.

Data Sources

Data sources include (1) EPA for the classified satellite imagery, select watershed delineations, and RF3 files; (2) NYCDEP for watershed and subwatershed boundaries and surface water chemical and biological data; (3) USGS for DEM, HUC, and stream discharge data; (4) Northeastern Regional Climate Center for precipitation data; and (5) Natural Resource Conservation Service (NRCS) for State Soil Geographic Data Base (STATSGO) and Soil Survey Geographic Data Base (SSURGO) soils data. Using these data, three types of statistical analyses were conducted.

Hiking trail and tributary near Bull Run, Rondout watershed.

Data Analyses

1) An average across the most recent 5 years of water data (1994 -1998) at each sample site (number of sites = 84) was used to examine the spatial trends in total nitrogen, phosphorus, and fecal coliform bacteria.

2) To study temporal variation of rainfall, discharge, and water quality, three sites (one water quality, one flow, and one rainfall) were selected in each of the six watersheds. These were the only sites where all three samples were taken within close proximity to each other (Figure 3.5). The discharge sites were located within a 1.5-km radius of a water quality sampling site. Precipitation sites were within a 1- to 22-km radius (average of 10 km or ~6 mi) of the water quality and discharge sample sites. Due to changes in total phosphorus collection methodology and limited total nitrogen data, temporal analysis includes only those measurements occurring between 1990 through 1998. However, fecal coliform bacteria data were from 1987 to 1998. Sampling times and frequency differed among the precipitation, discharge, and concentration data sets. Therefore, in order to relate the data for time series analyses, monthly averages were calculated synchronizing in time the precipitation, discharge, and concentration data (Box and Jenkins, 1976).

Changes in total nitrogen, total phosphorus, and fecal coliform bacteria over time were analyzed using auto-regression analyses. This type of analysis addresses serial correlation effects that can

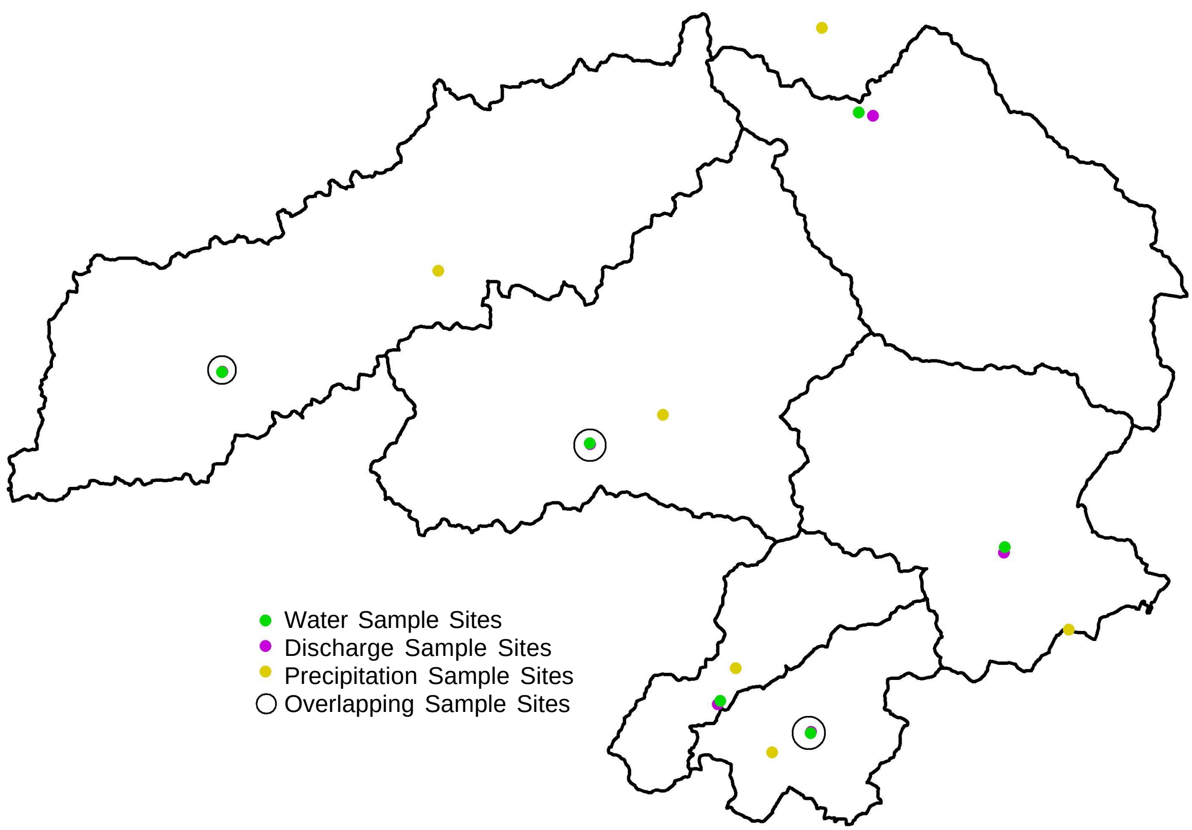


Figure 3.5. *Location of the rainfall, discharge, and water quality sample sites used to examine temporal variation in each of the Catskill/Delaware watersheds.*

result from temporal data (SAS,1990). Monthly data from 33 sites were used to characterize these trends. Prior to auto-regression analyses, data were log-transformed to homogenize and stabilize dependent variances. The spatial and temporal analyses results are discussed in Chapter 6.

3) Stepwise multiple regression analyses were conducted on three sets of landscape and water quality data to determine the contribution of various land uses, measured as landscape metrics, to surface water total nitrogen, phosphorus, and fecal coliform bacteria (SAS, 1990). Water quality data from 32 selected water sampling sites (Figure 3.2) and the landscape metric percentages for the watersheds were used in the regression analyses.

The total nitrogen, phosphorus, and fecal coliform bacteria data were averaged over the years around the imagery as follows: average water data from 1994 to 1998 were paired with the late 1990s land cover classification; average water data from 1989 to 1993 were paired with the early 1990s land cover classification; average water data from 1987 to 1988 were paired with the mid-1980s land cover classification. The water data were log transformed to eliminate seasonal effects and linearize the relationship with landscape metrics (Jones et al., 2001).

Prior to stepwise regression, pairwise correlations were examined to detect any high colinearity (similarity) between the landscape metrics (Griffith and Amerhein, 1997). Inclusion of highly similar landscape metrics can interfere with regression analyses, resulting in unreliable predictions of the landscape relationships to water quality (Berry and Felman, 1985). When two landscape metrics were determined to be highly correlated, one was excluded from the regression analysis. A further set of statistical tests was conducted to determine data normality, randomness, and outliers (Madanskey, 1988).

In order to validate the final stepwise regression models, a set of four surface water sample sites and their corresponding land cover percentages were withheld from the regression model. Model accuracy was determined by how well the withheld site means fit within the 95% confidence interval of model predicted values from subwatersheds having comparable land use. The results from the model validation and predictions are presented in Chapter 7.

Chapter 4. Land Cover/Use

In this chapter a number of landscape metrics are used to assess environmental conditions in Region 2 and Catskill/Delaware watersheds. Each metric is discussed separately with maps illustrating the relative ranking of the watersheds or subwatersheds. The metrics and the accompanying interpretation are not exhaustive but focus on those expected to be relevant to water quality.

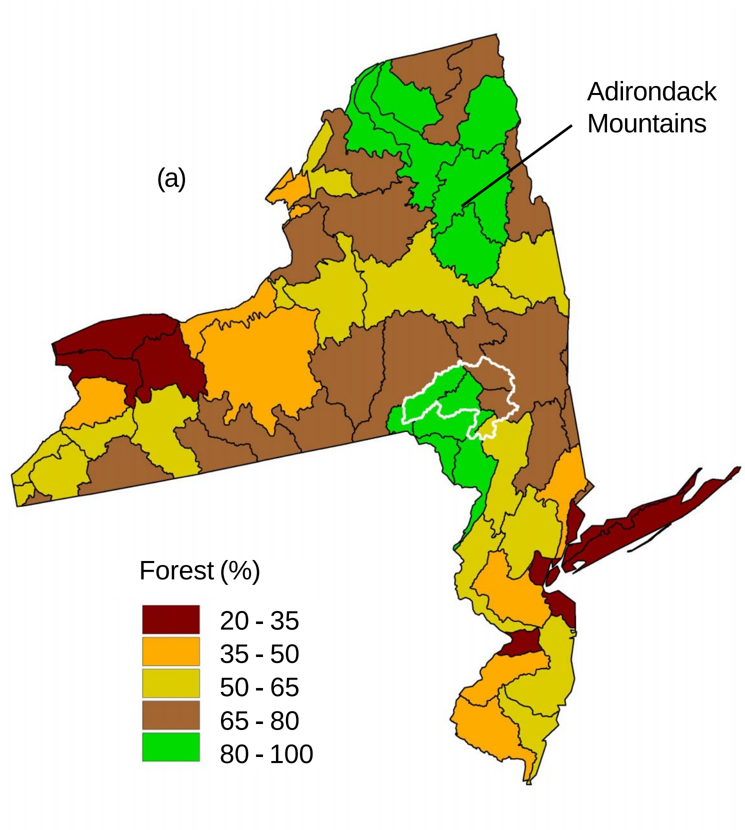
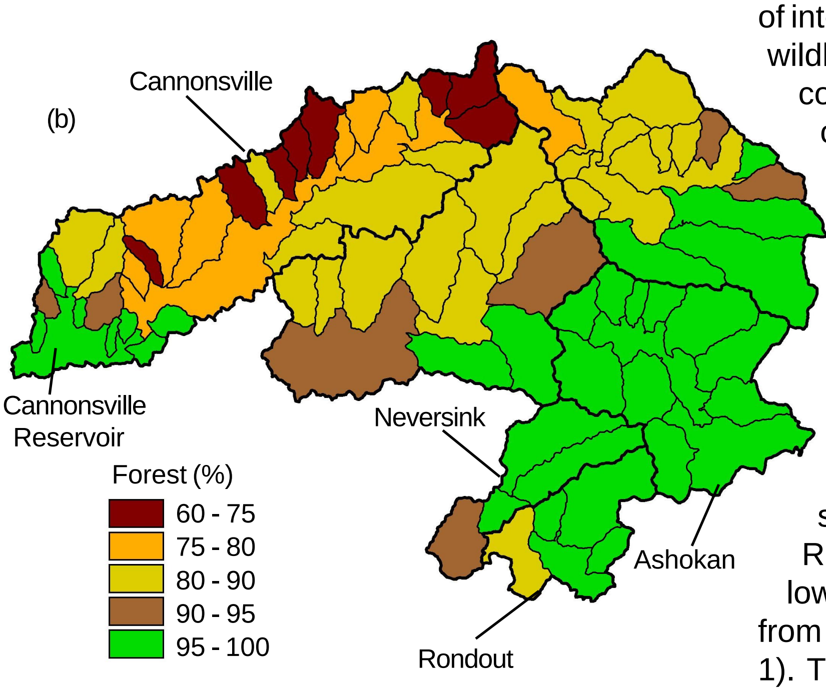


Figure 4.1. *Percentage of forested land cover in **(a)** Region 2 watersheds and **(b)** the Catskill/Delaware subwatersheds. The metrics were calculated as total area divided by total watershed*

Forest Land Cover

Trees are an important element of both natural and human-dominated landscapes. Forests provide benefits to humans and wildlife such as wood fiber, outdoor recreation, habitat, and regulation of hydrologic flow. The proportion of forest cover can influence rainfall impacts and surface runoff properties within a watershed. The deeper roots and higher water interception in forested soil helps reduce runoff and erosion into surface water (Novotny and Olem, 1994).

Historic patterns of land use, development, and forest regrowth in Region 2 have created the present distribution of forest from what once was essentially all forest (Forman, 1995a). For most of Region 2, forest remains the dominant land cover type covering approximately 60% of the area. The watersheds in the interior portions of the Adirondack Mountains approach complete forest cover (97%; Figure 4.1a; Table B-1). These watersheds contain large tracts of interior forest, providing habitats for a variety of wildlife species. The lowest percentage of forest cover is about 21% in the more developed coastal watersheds to the east. Forests within these watersheds would be smaller and farther apart having a greater proportion of edge than interior forest habitat.



Like the Appalachian watersheds, the CD watersheds are dominated by evergreen and deciduous forest with an average cover of 89%. The forest cover largely consists of secondary regrowth. With the exception of the subwatersheds surrounding the Cannonsville Reservoir, the general spatial distribution (from lowest to highest percentage of forest cover) is from northwest to southeast (Figure 4.1b; Table C-1). Three of the six watersheds (Ashokan,

Table 4.1. Late 1990s Land Cover/Use Percentages in the Catskill/Delaware Watersheds

Watershed	Forest (%)	Urban (%)	Agriculture (%)	Barren (%)	U-Index (%)	Ag Slope >5% (%)
Cannonsville	80	1	19	< 1	20	13
Schoharie	91	< 1	8	< 1	9	4
Pepacton	90	< 1	9	< 1	10	7
Ashokan	98	1	1	< 1	2	< 1
Neversink	98	< 1	2	< 1	2	1
Rondout	96	< 1	4	0	4	3

Neversink, and Rondout; Table 4.1) have forest cover averages greater than 95%, and roughly half of all the CD subwatersheds have greater than 90% forest cover. Only eight subwatersheds have forest cover under 75%; all are located within the Cannonsville watershed.

Agriculture

According to the United States Department of Agriculture Statistics Service, approximately 8 million acres are dedicated to the production of livestock, grain, and specialty crops within New York and New Jersey (USDA, 1999). Production from these lands includes around 80-million bushels of grain, 300-million pounds of meat, and 1.5-billion gallons of milk. From these numbers it is easy to see that livestock play a major role in the commerce and community structure within Region 2. In order to support the high production of both forage (grass) and grain crops (corn and wheat), tons of fertilizer are applied every year. Despite the obvious production and greening benefits gained by the application of fertilizer, there is the potential for negative repercussions on water quality from nutrient runoff (Heathwaite et al., 1990). Due to its influence on society and the environment, agriculture is an important land use for Region 2.

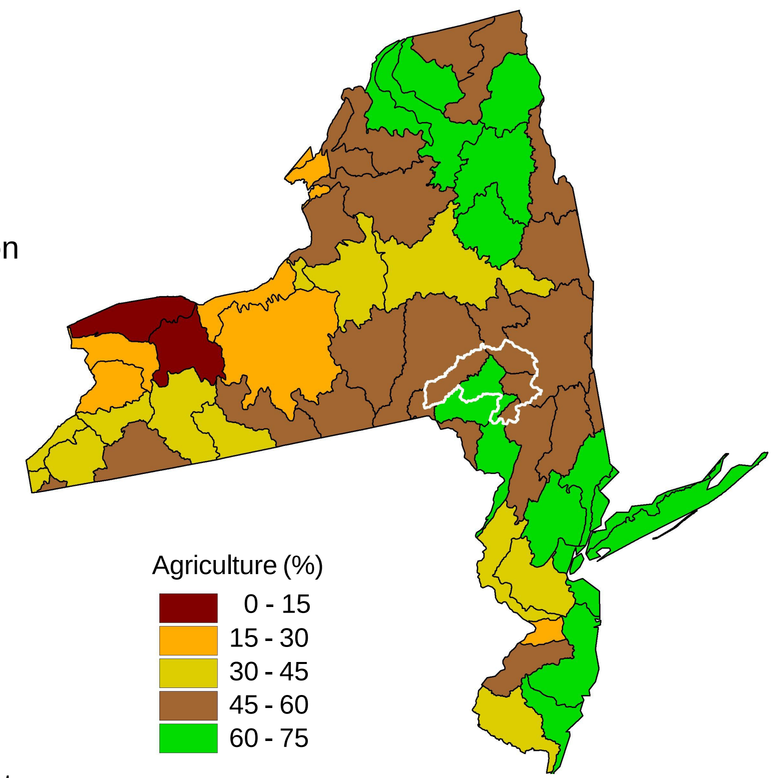


Figure 4.2. *Percentage of agriculture land cover in Region 2 watersheds The metrics were calculated as total agriculture area divided by total watershed area.*

The percentage of land devoted to agriculture averages 25% across all watersheds in the two states, with a range from 1 to 75% (Figure 4.2; Table B-1). However, the median percentage of agricultural land use across all watersheds is equal to the average percentage of agriculture, suggesting a fairly even distribution across Region 2. The location and type of farming practiced can be tied directly to the biophysical and climatic settings of the area. Steep slopes, shallow soils, and a shorter growing season tend to limit the mountainous parts of Region 2 to raising livestock. However, the gently rolling lands of the western plateau provide fertile ground for cultivation of field crops.

Compared to Region 2, the percentage of land in agriculture is not as large in the CD watersheds (Figure 4.3; Table C-1). However, the average percentage of agriculture across all CD watersheds is 10%, making it the most common human use of the land in the area. Most farming in this area consists of pastures for livestock and hay production and is concentrated in the northwest. Close to 20% of the Cannonsville watershed is devoted to agricultural use with eight subwatersheds having the highest percentages of agriculture (over 25%) in all the CD watersheds. The Pepacton and Schoharie watersheds average about 10% agriculture in the watersheds and subwatersheds. The remaining watersheds (Neversink, Rondout, and Ashokan) average 3% or less total agricultural.

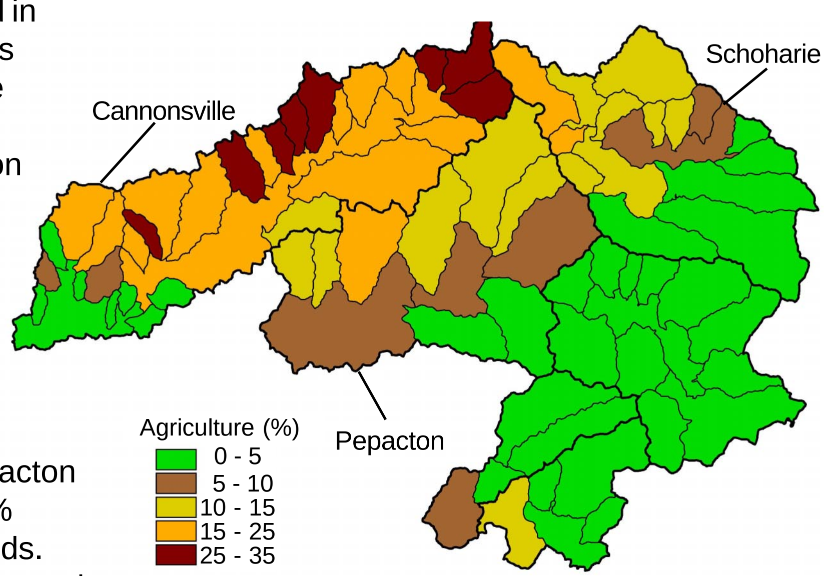


Figure 4.3. *Percentage of agriculture land cover in the Catskill/Delaware subwatersheds. The metrics were calculated as total agriculture area divided by total watershed area.*

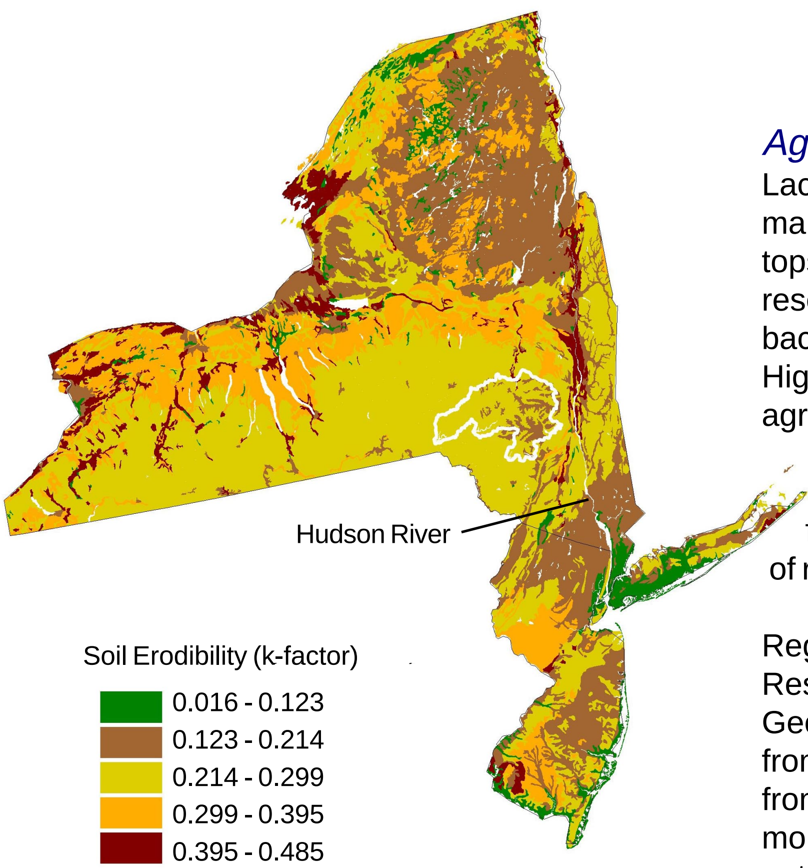


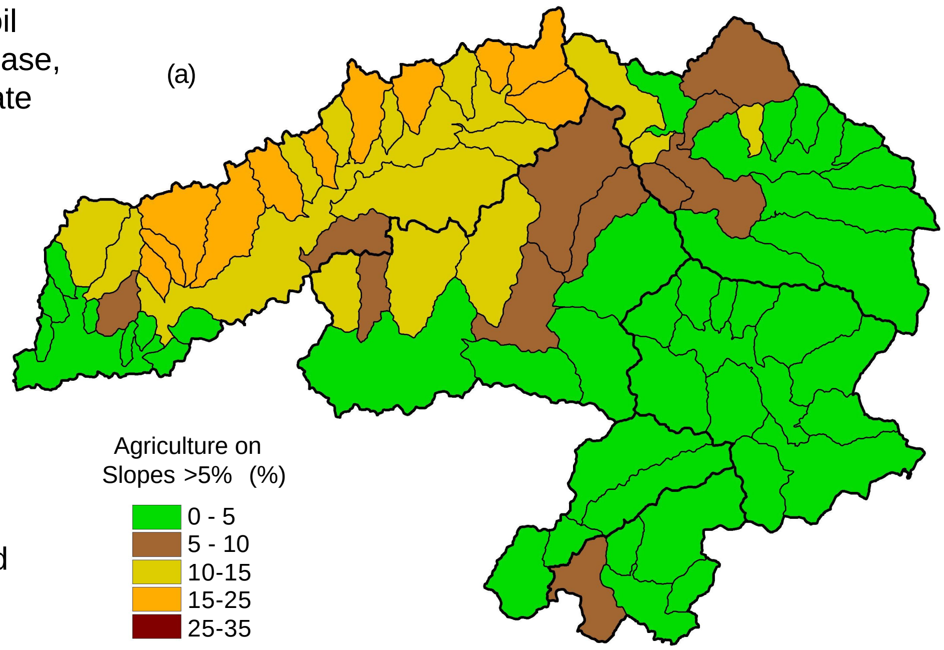
Figure 4.4. *Average soil erodability factor (k-factor) for Region 2. Source: Natural Resource Conservation Service, State Soil Geographic Data Base.*

Agriculture on Erodible Soils

Lack of vegetative cover and poor land management practices result in the transport of topsoil to streams and reservoirs. Sediments fill in reservoirs and carry nutrients and fecal coliform bacteria which impairs water quality in streams. Highly erodible soils are of particular concern, since agriculture on these soils results in a higher rate of soil erosion (Johnes and Heathwaite, 1997). The potential for erosion, expressed as the k-factor, is used to evaluate the relative erodibility of regional and CD water supply watershed soils.

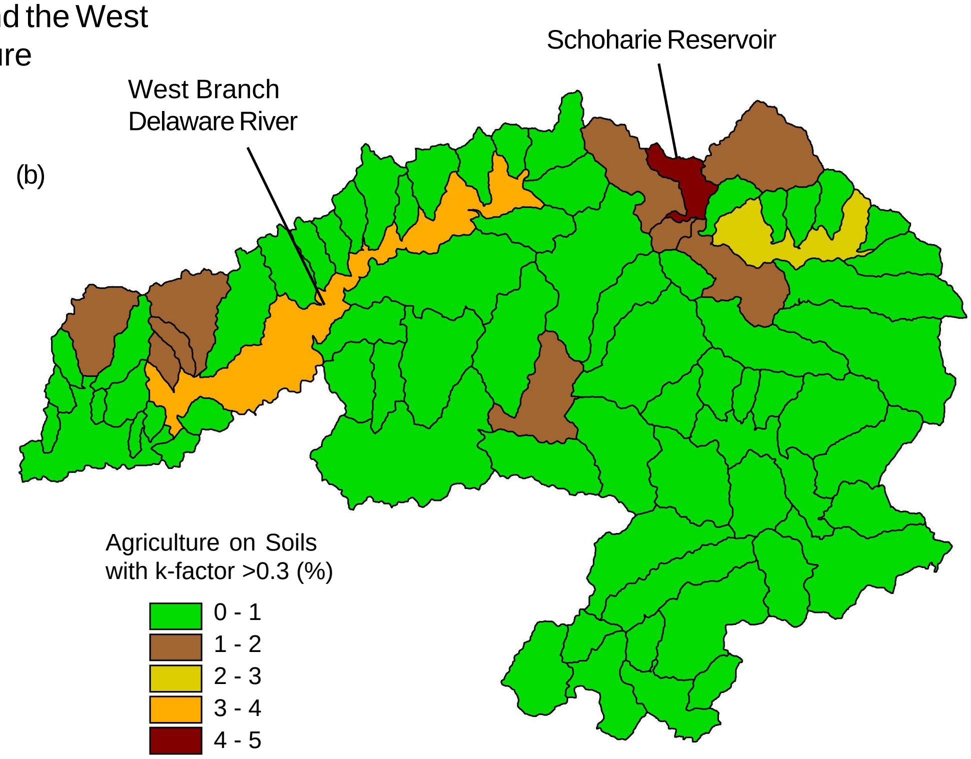
Regional soil k-factors are derived from the Natural Resource Conservation Service (NRCS) State Soil Geographic (STATSGO) database and they range from 0 to 0.49 (Figure 4.4). The k-factor is derived from soil texture and slope conditions. A k-factor of more than 0.3 is an indication of high erosion potential (Brady, 1990). In New York the most erodible soils are located in the northwest and around the Hudson River, while in New Jersey the potential for erosion is the highest in the southwestern part of the state.

In the CD watersheds the soil k-factors are derived from the finer scale NRCS Soil Survey Geographic (SSURGO) database, which provided a better spatial estimate of soil erosion potential. The most erodible soils in the watershed are located on hill slopes or on valley floors near streams. To evaluate the watershed's relative risk for soil loss, metrics for agriculture on erodible soils and agriculture on slopes >5% were calculated by overlaying the SSURGO and elevation data.



In the CD watersheds, close to half of the total agriculture acreage is located on hill slopes greater than 5%. Subwatersheds with the greatest proportion of agriculture on slopes greater than 5% corresponded with those having the highest overall percentage of total agriculture (Figure 4.3; Figure 4.5a; Table C-1). Greater than one third of the total agriculture within the CD watersheds is located on soils having a k-factor greater than 0.3. The greatest percentage of agriculture on highly erodible soils is located in the subwatersheds around the Schoharie Reservoir and the West Branch of the Delaware River (Figure 4.4b; Table C-2).

Figure 4.5. ***Figure 4.5.*** *Percentage of Catskill/Delaware subwatersheds with agricultural land use on* ***(a)*** *slopes >5% or* ***(b)*** *soils with k-factor values >0.3. The metrics were calculated by overlaying maps of slope and land cover and dividing the area of agricultural use on slopes >5% or agriculture on highly erodible soils (k >0.3) by the total subwatershed area.*



Roads

Roads are necessary to connect people with towns, recreational sites, agricultural fields, and ecological communities. The influence of a given road on the surrounding environment extends for some distance, depending on road size, surface type, traffic volume, and type of use (Forman and Deblinger, 2000). The construction and maintenance of roads can cause permanent stress (altered flow and sediment deposition) on nearby streams. The impervious nature of road surfaces and the ditches built to channel water off roads influence the rate of water runoff which can carry salt, petroleum products, antifreeze, and other vehicle-related chemicals into nearby streams. Another influence roads may have is the enhancement or impairment of species migration and habitat (Dijak and Thompson, 2000). Road density and number of roads crossing streams are important measurements to include in an environmental assessment. The road metrics are calculated from 1:100,000 USGS Digital Land Graph (DLG) data.

A map of relative road density is used to indicate total number of roads in Region 2 watersheds (Figure 4.6; Table B-1). There are about 240,000 km of roads in Region 2, with the highest road density 10 km/km^2 (16 mi/mi^2) located around the Long Island Sound. For the most part, the rest of Region 2 watersheds have road densities between 1 and 2 km/km^2.

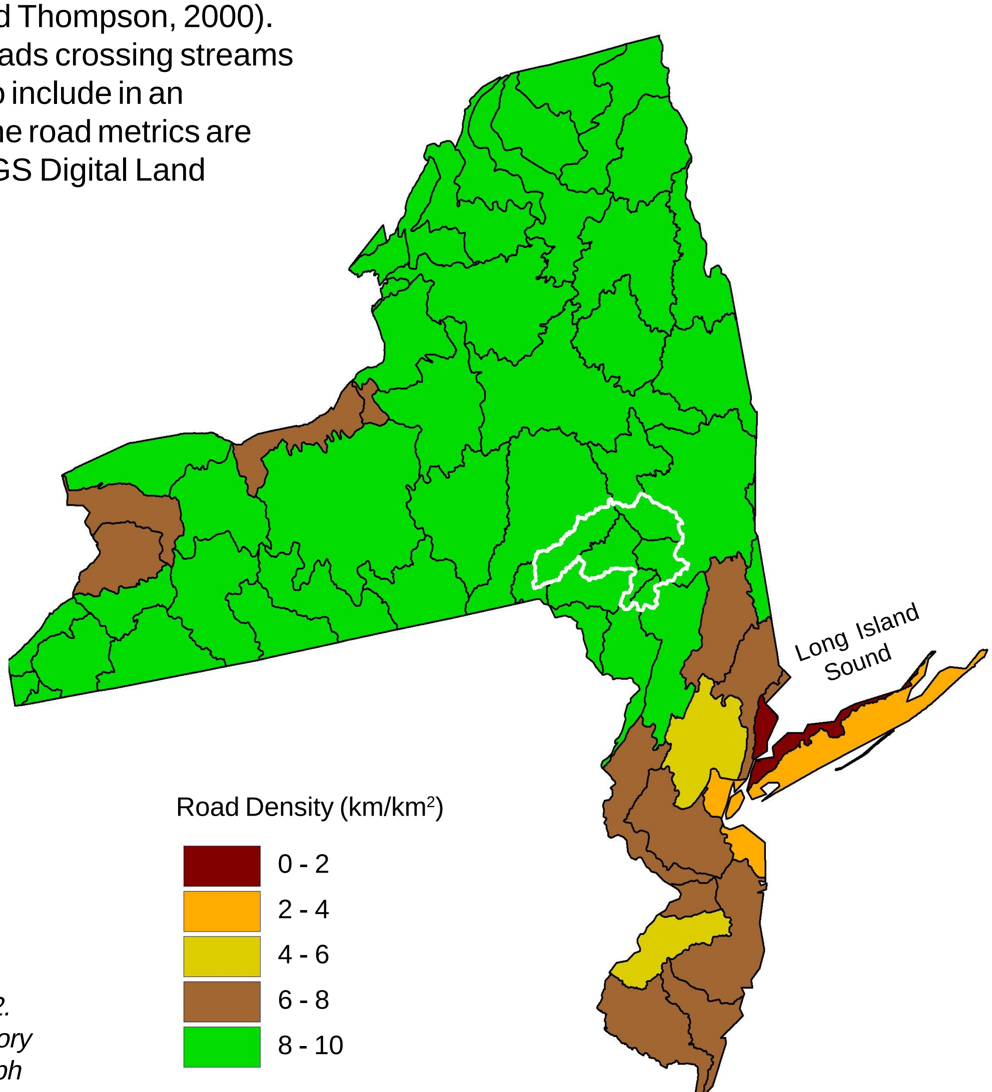


Figure 4.6. *Road density in Region 2. The metric was based on road catagory classes 1-4 (USGS Digital Land Graph data) and is calculated as length of road per total watershed area.*

The distribution of roads appears to be fairly even across the CD watersheds, with the majority of the subwatersheds averaging between 0.9 and 1.5 km/km^2 (1.5 to 2.4 mi/mi^2; Figure 4.7; Table C-2). There are 4,000 km (2,485 mi) of roads in the CD watersheds. The topography forces many of the roads to run parallel to the stream where the land surface is flatter. Road density within a 60-m buffer from streams varied from 0 to 0.5 kilometer of road per kilometer of stream. Invariably these roads end up intersecting with the numerous streams. In each of the three watersheds (Cannonsville, Pepacton and Schoharie; Figure 4.8) there are over 1,000 places each where roads intersect or cross streams. Seven subwatersheds within the Cannonsville watershed have stream crossing densities greater than one crossing per kilometer of stream (1.61 crossing/mi; Figure 4.8; Table C-2). The Ashokan watershed has the second highest number of stream crossings and one of the four subwatersheds with the highest density of crossings.

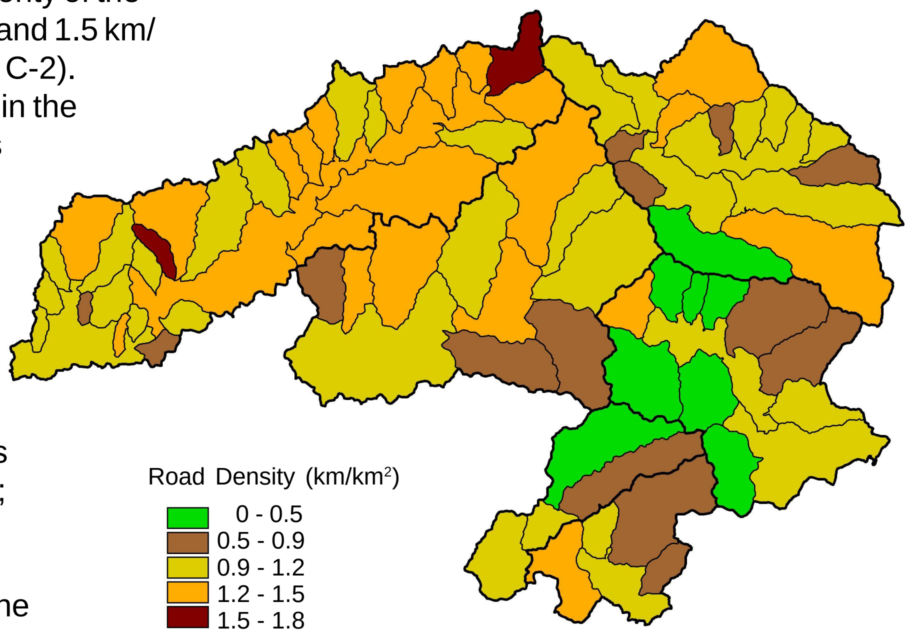


Figure 4.7. *Road density in the Catskill/Delaware subwatersheds. The metric was calculated as length of road (km) per total subwatershed area (km^2).*

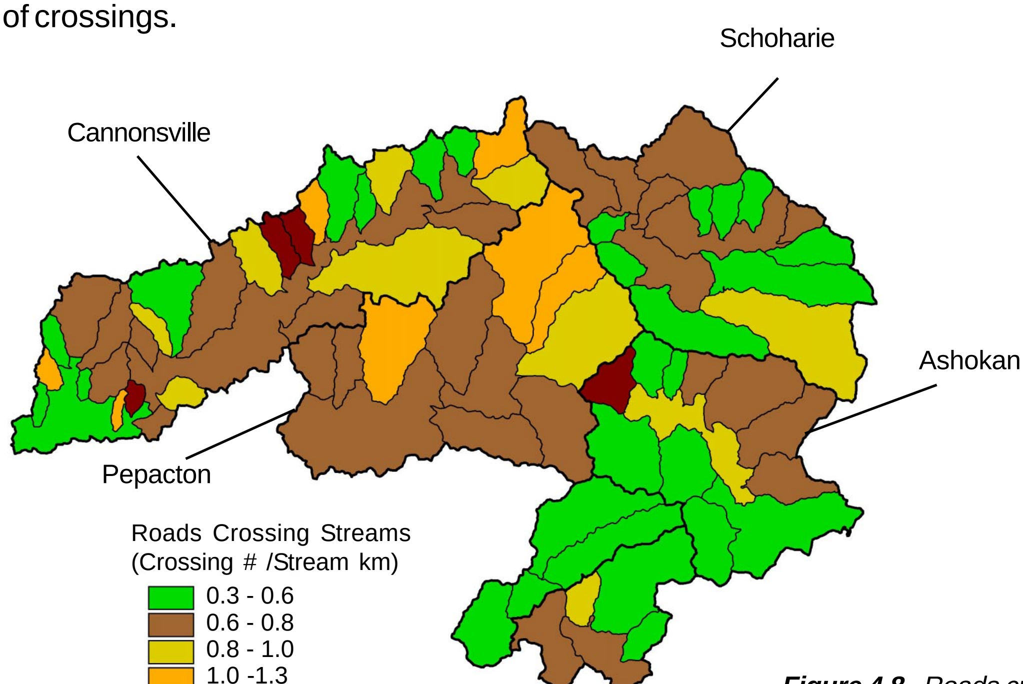


Figure 4.8. *Roads crossing streams in the Catskill/Delaware subwatersheds. The metric was calculated as total number of crossings per total length of stream in the subwatershed (km).*

Population Growth and Urban Development

According to the United States Bureau of the Census, the population in 1990 was estimated at close to 18 million for New York and 7.7 million for New Jersey (U.S. Census, 1990). When converted to population density, there were 380 people per square mile for New York and just over 1,026 per square mile for New Jersey. As of 1990 close to 10 million people resided in the city of New York and surrounding areas. The population density in the watersheds surrounding New York City is orders of magnitude higher than in the rest of the state, where there is considerably lower density. This diverse pattern is reflected in the map of urban development (Figure 4.9; Table B-1). Urban development averages 10% of the total area, with the higher concentrations located in watersheds containing the major cities of New York, Newark, and Trenton. In these metropolitan-dominated watersheds, urban development is as high as 70%, while many of the watersheds in the mountainous regions of New York approach near zero development. This unequal distribution of development results in a median value of about 4% urban development for the watersheds of Region 2.

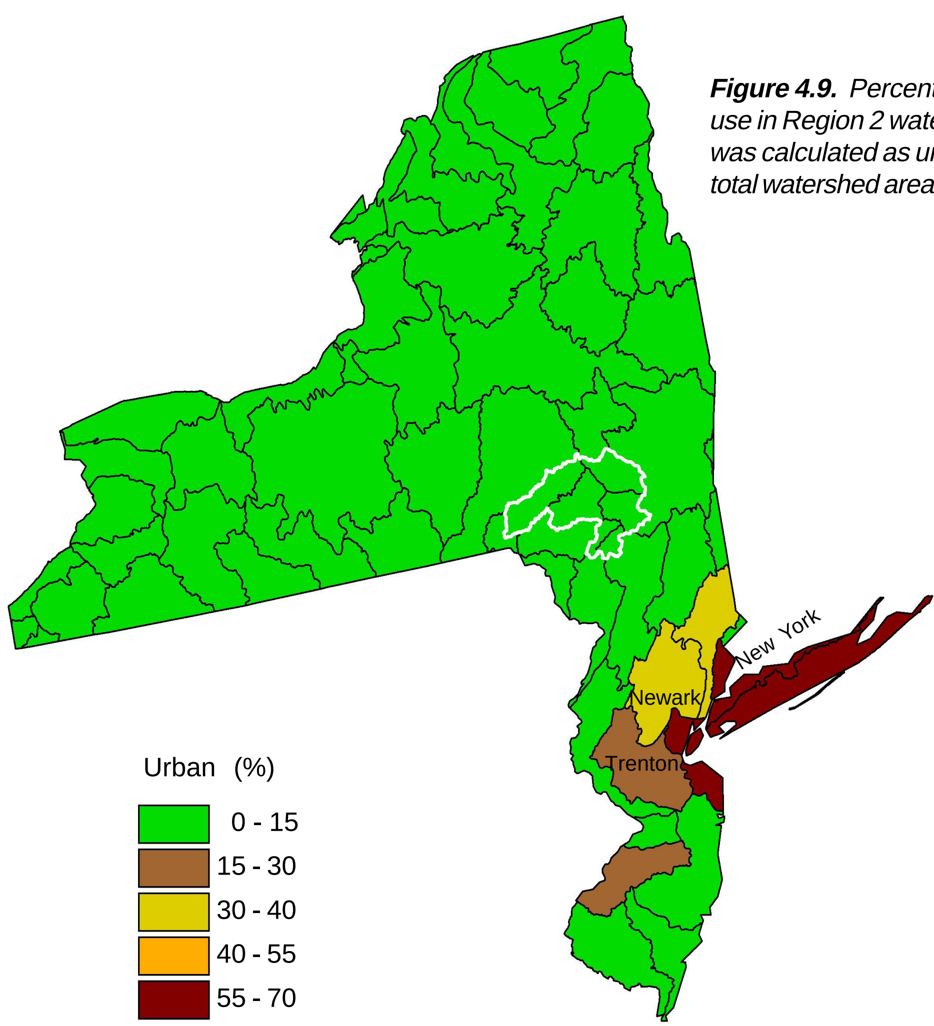


Figure 4.9. *Percentage of urban land use in Region 2 watersheds. The metric was calculated as urban area divided by total watershed area.*

From 1970 to 1995, population in the CD watersheds increased by only 15% from 53 to 64 thousand people (Figure 4.10). Urban land use averages less than 1% of the total area and consists of small residential towns. The urban development in the area is focused around agriculture in the west and tourism in the east (Stave, 1995). This has led to pockets of growth near the reservoirs, ski resorts, and areas of high agricultural production. The greatest amount of urban land use in the Schoharie and Pepacton watersheds is located within subwatersheds containing ski resorts and other tourist attractions (Figure 4.11; Table C-1). In the Cannonsville watershed, average urban land use in the subwatersheds ranges from 0 to 3.7%. The majority of the urban land use in the Ashokan watershed is located around and upstream of the reservoir. The remaining watersheds (Neversink and Rondout) have minimal urban land use.

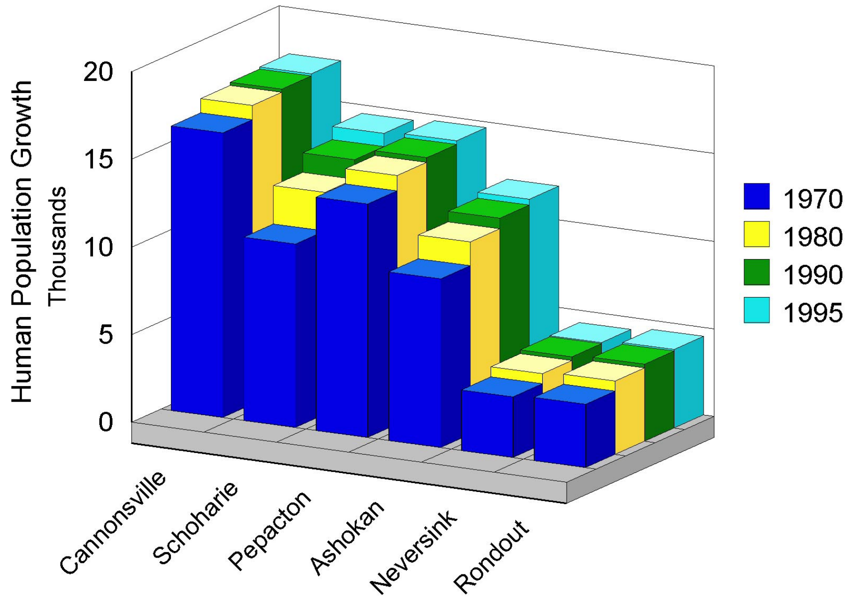


Figure 4.10. *Population change within the Catskill/ Delaware watersheds. County level census data were modified using 1990 estimates of within-watershed population. Source: U.S. Census Bureau county data 1970 to 1995 modified using New York City Department of Environmental Protection 1990 estimated within-watershed population totals.*

As a result of topographic constraints, much of the human use within the watersheds has concentrated close to rivers and streams. Therefore, while the human population only marginally increased in the past 30 years, the location of urban use near watershed streams increases the potential for continued effluent from waste treatment plants, nonpoint agricultural, and urban runoff to enter streams.

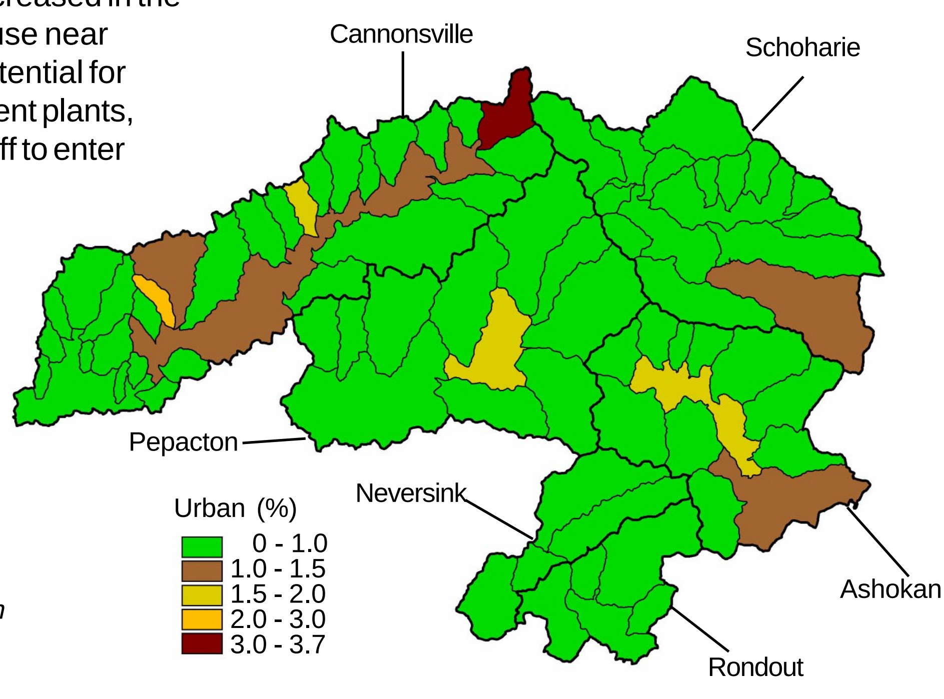


Figure 4.11. *Percentage of urban land use in the Catskill/Delaware subwatersheds having urban land use. The metric was calculated as total urban area divided by total subwatershed area.*

Human Use Index

While the proportion of developed land use gives an indication of urban development within an area, a more accurate picture of human influence on the landscape can be mapped with the human use index (U-index). The human use index combines the proportions of agriculture, barren, and urban land use into a single measure. By looking at watershed patterns of the U-index, it is possible to identify those areas which have experienced the greatest land conversion from natural vegetation cover (O'Niel et al., 1988).

The highest U-index for Region 2 is about 78% and the lowest is 1.5% with a median value of 34% (Figure 4.12; Table B-1). Agriculture is the dominant component of the U-index in watersheds located outside major metropolitan areas. In contrast, the watersheds located in close proximity to Long Island Sound have a U-index dominated by urban. The lowest U-index values are in watersheds containing the Adirondack and Catskill Mountains. The soils of these watersheds are generally too shallow for agriculture and difficult to build homes on due to topography.

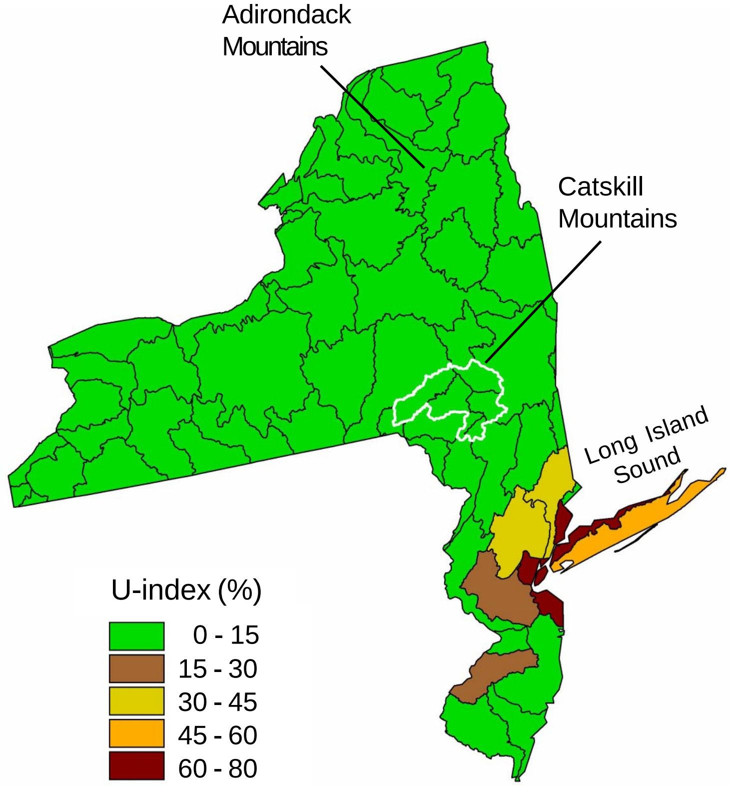


Figure 4.12. *Percentage of watershed in human land use in Region 2. The U-index was calculated as total urban and agricultural area divided by total watershed area.*

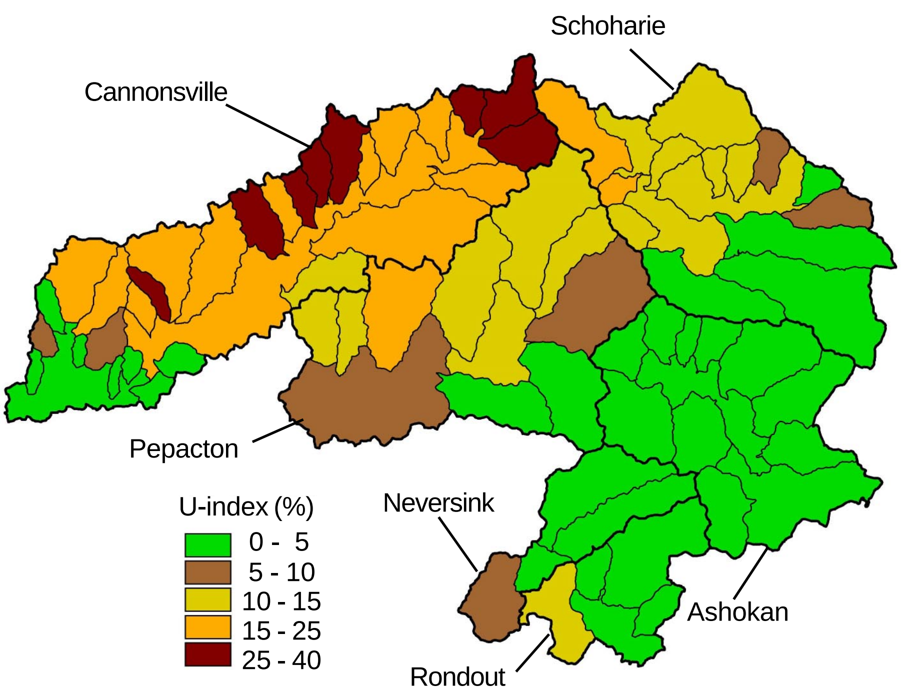


Figure 4.13. *Percentage of the Catskill/Delaware subwatersheds in human land use. The metric was calculated as total urban, agricultural, and barren area divided by total subwatershed area.*

The higher percentages of agricultural and barren lands in the Cannonsville, Pepacton, and Schoharie watersheds resulted in higher U-index values than for the other three subwatersheds (Table 4.1). Although the Ashokan has the highest percentage of urban use, its U-index is similar to that of the Neversink and Rondout watersheds. With the exception of two subwatersheds, one in Schoharie and one in Pepacton, the U-index rankings remain identical to those for subwatershed total agriculture (Figures 4.3 and 4.13; Table C-1).

Riparian Land Cover/Use

Nonpoint source pollution continues to be a concern to regional and local water resource managers. Since the 1970s, research has shown a link between near stream vegetation and water quality measurements (Karr and Schlosser, 1978). A designated distance from a stream is called a riparian buffer. Natural vegetation in the riparian buffer can provide an effective barrier to stream bank erosion and runoff of water pollutants such as excess fertilizer. In addition, riparian vegetation supports a variety of valuable plant and wildlife species (Lowrance, 1997). Characterization of riparian conditions over the entire region can help to identify watersheds that might benefit from riparian improvements.

The relative amount of forest and human use in a 60-m riparian buffer (each side of streams) within Region 2 watersheds can be seen in Figure 4.14 and Table B-2. The ranking of all riparian land cover/use metrics is similar to the total watershed assessment, with only slightly lower proportions in the riparian buffer area (Tables B-1 and B-2). The range of human use within the 60-m buffer is between 2 and 70%. Human use averages 30% of the total riparian area, with agriculture land use accounting for close to three quarters of that amount. In the more mountainous areas where human use is concentrated in the flatter flood plains, a larger proportion of the total agricultural acreage within the watershed is located within 60 m of the stream.

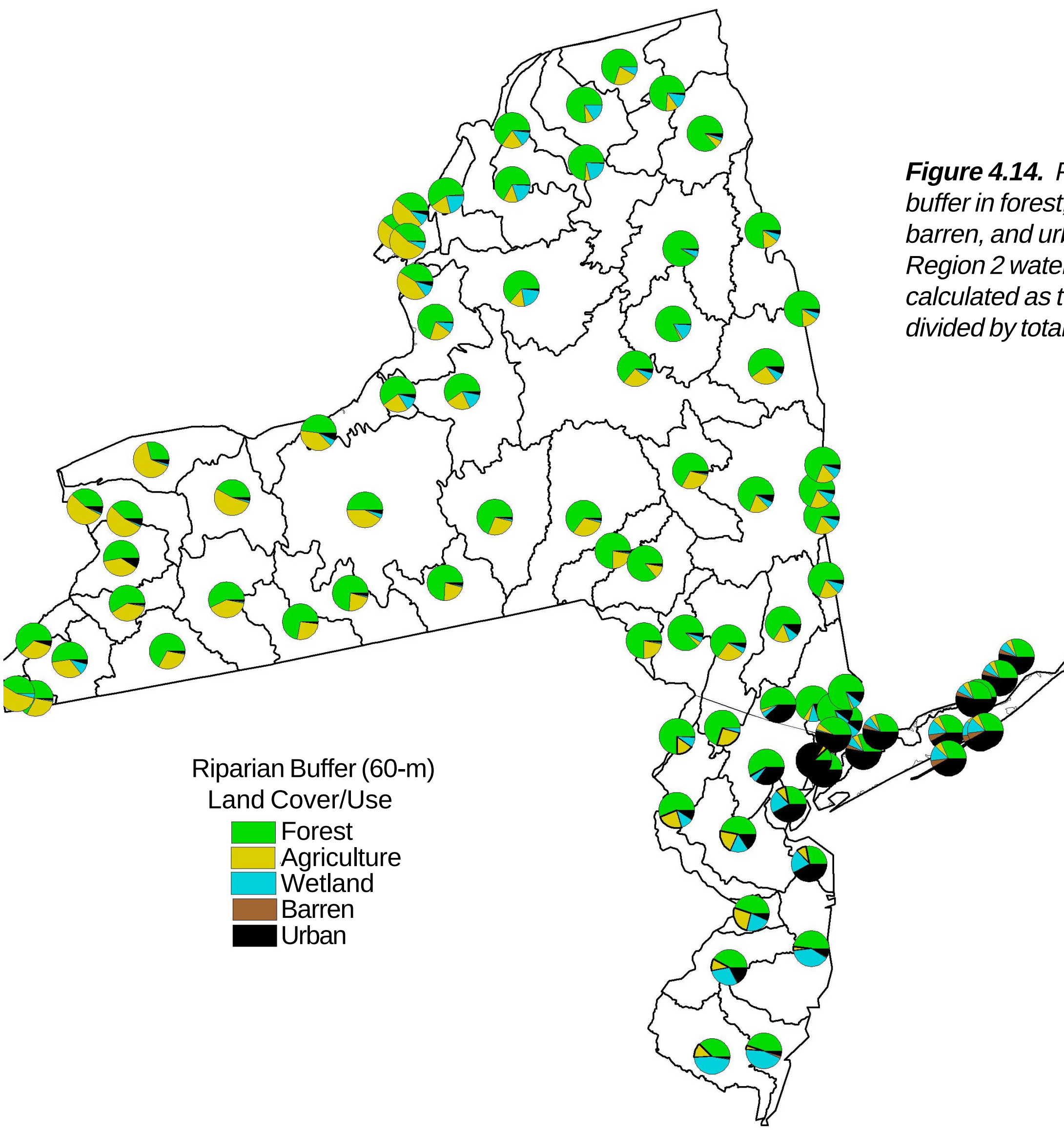


Figure 4.14. *Percentage of the riparian buffer in forest, agriculture, wetland, barren, and urban land cover/use in the Region 2 watersheds. The metrics were calculated as total land cover/use area divided by total watershed area.*

In the CD watersheds there are around 7,000 km (4,350 mi) of streams. Buffer distances of 30, 60, and 120 m on both sides of the streams are used to calculate land cover/use metrics. The average riparian forest cover within the subwatersheds is about 5% lower than that of the whole subwatershed. Table 4.2 gives the average land cover percentages for the CD subwatersheds and 60- and 120-m riparian buffers. Forest cover percentages did not vary between 30 and 120 m. The lower forest cover in the riparian is, for the most part, due to greater proportions of agriculture. The flatter topography surrounding the streams is often the only place available for agricultural production, particularly row crops. The percentage of agriculture in the riparian buffers ranges between 15 and 44%. The agriculture in the CD riparian buffer often makes up between 10 to 100% of the total subwatershed agriculture. The lowest forest and highest agricultural riparian coverage are in the subwatershed of the Cannonsville and Pepacton watersheds (Figure 4.15; Table C-3). The riparian human use index is mostly related to percent total agriculture in the subwatersheds. However, in the Ashokan and Schoharie watersheds the most eastern subwatersheds have high percentages of urban development which placed them into a lower U-index ranking.

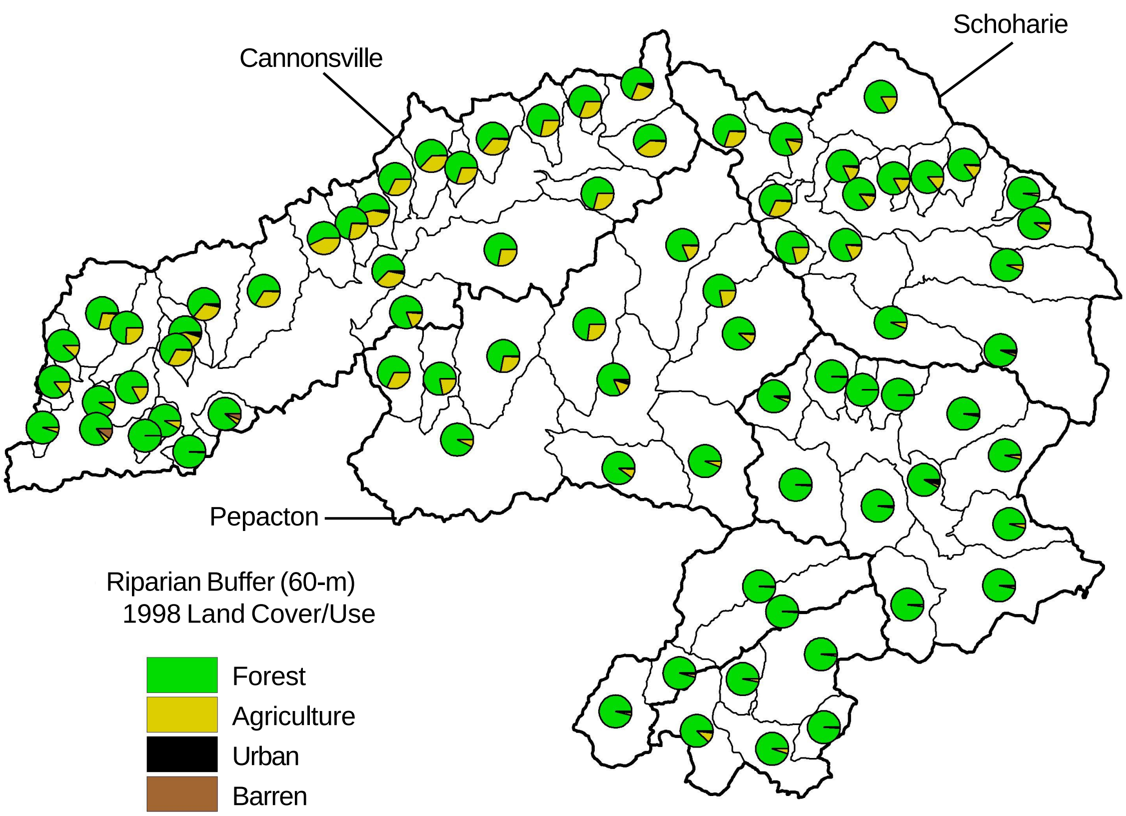


Figure 4.15. *Percentage of the riparian buffer in forest, agriculture, urban, and barren land cover/use in the Catskill/Delaware subwatersheds . The metrics were calculated as total land cover/use area within a 60-m buffer divided by total subwatershed area.*

Table 4.2. Descriptive Statistics for the Catskill/Delaware Subwatersheds and Riparian Buffers

Metric	Mean	Median	Minimum	Maximum
Subwatersheds				
Forest (%)	89	90	64	100
Urban (%)	< 1	< 1	0	2
Agriculture (%)	10	9	< 1	35
Barren (%)	< 1	0	0	3
U-Index (%)	11	10	< 1	36
Ag. (%) on Slope 5%	7	5	< 1	24
Ag. (%) on Slope 15%	< 1	< 1	0	1
Stream Length (m)	86,833	63,192	5,017	416,591
Stream Density (km/km^2)	2	2	1	3
Road Length (m)	51,920	38,240	2,678	298,501
Road Density (km/km^2)	1	1	< 1	2
Xing Count (#)	60	41	3	282
Riparian Buffers				
Forest (60 m) (%)	84	85	54	100
Agriculture (60 m) (%)	15	13	< 1	44
Urban (60 m) (%)	1	< 1	0	6
Barren (60 m) (%)	< 1	0	0	11
U-Index (60 m) (%)	17	15	< 1	47
Road Near Stream (60 m) (m/m)	< 1	< 1	< 1	< 1
Forest (120 m) (%)	84	86	53	100
Agriculture (120 m) (%)	15	14	< 1	44
Urban (120 m) (%)	1	< 1	0	5
Barren (120 m) (%)	< 1	0	0	7
U-Index (120 m) (%)	16	14	< 1	47

Landscape Summary

There is a wide range of land use across Region 2 watersheds. The variability in the regional landscape is the result of the interactions between topography, soil, climate, vegetative land cover, and human use. The coastal areas of New Jersey contain both large amounts of urban development and wetland habitat, while upstate New York has large tracts of forest interspersed with small farm community towns. The Long Island Sound area is largely dominated by cities and a vast number of interlacing roads, while the northwest has a large agricultural base. The mountainous areas, including the CD watersheds, are dominated by forest cover with small pockets of rural towns and agriculture located within the riparian buffer.

In the CD watersheds the human use, which is dominated by agriculture, is highest in the northwest watersheds and lowest in the southeast watersheds. The lowest overall forest cover is within the subwatersheds of the Cannonsville watershed, while the Rondout and Neversink have forest cover approaching 100%. The mountainous topography creates a situation where close to half of the total agricultural acreage is found on slopes greater than 5%. The amount of human use in the riparian buffer is also influenced by topography. The results from the 60- and 120-m buffer assessment indicate that riparian land use/cover parallels the watershed as a whole, having slightly greater percentages of agriculture and urban development.